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# JOURNAL

VOLUME 12, NUMBER 10 • OCTOBER, 1956

## Plastic Truck Conversion

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This one-piece plastics truck cover will convert an open bed pick-up truck to a panel model in a matter of minutes. Manufactured by Glas Laminates, Inc. of Costa Mesa, California from glass fiber reinforced polyester resin, the rugged cover seals out rain and dust, resists shock and temperature change.

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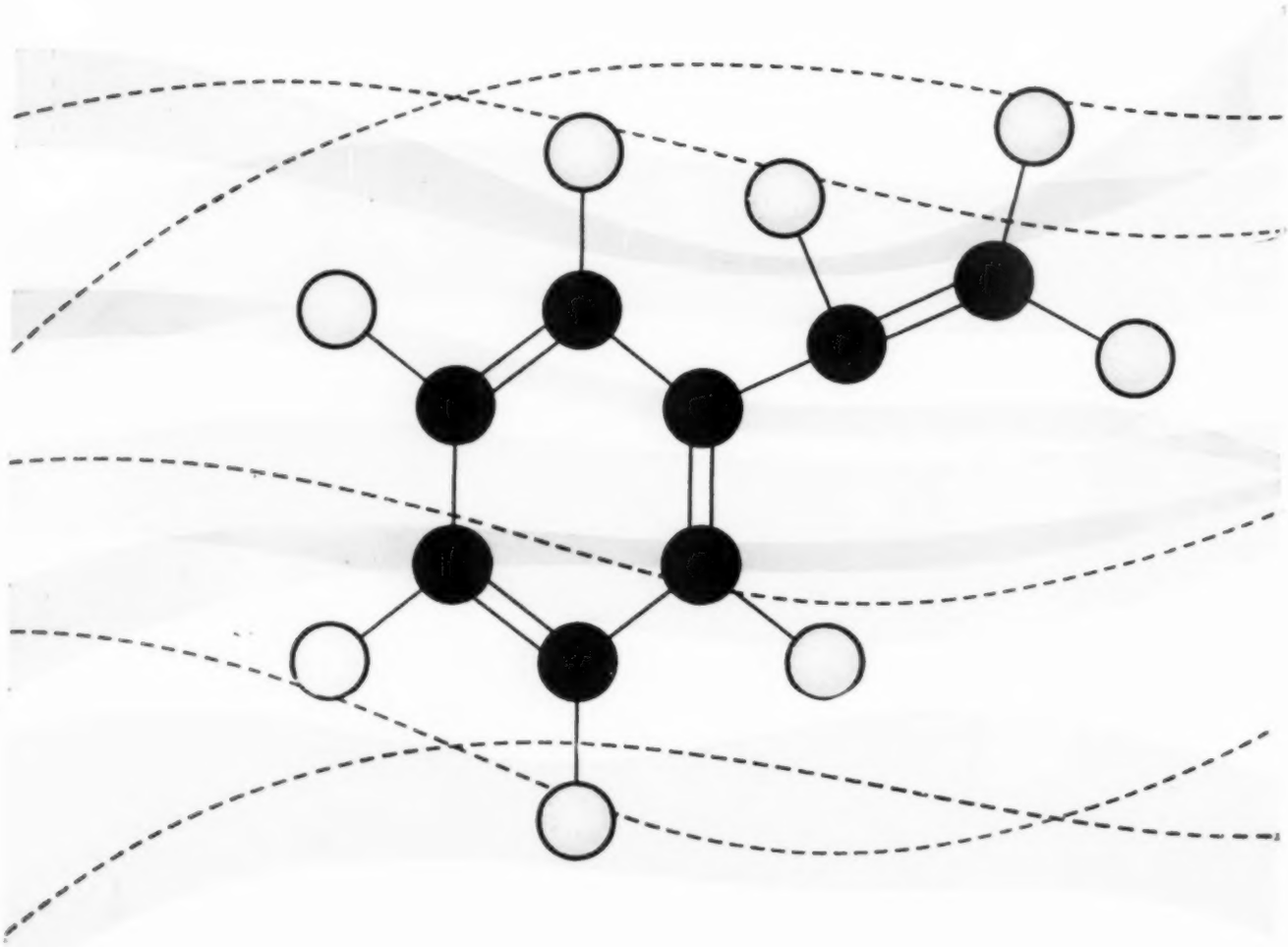
# STYRENE



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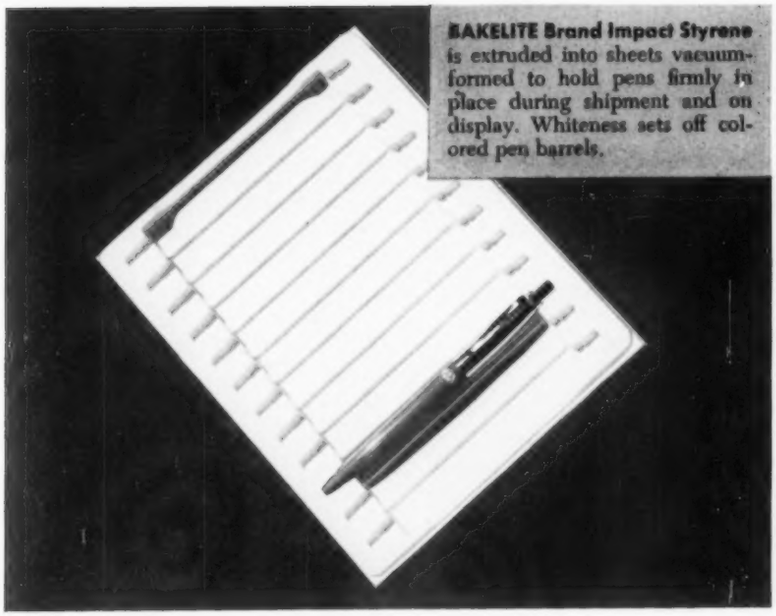
**BAKELITE Brand Phenolic BMG-8335 Black 35** has been used for almost ten years by the manufacturer of these cooking utensil handles—striking evidence of this material's satisfactory service.

**BAKELITE Brand Polyethylene** is used for pouring spout on this metal can. Flexibility permits high-speed assembly-line attachment, chemical resistance assures corrosion-free operation.



**BAKELITE Brand Impact Styrene** is extruded into sheets vacuum-formed to hold pens firmly in place during shipment and on display. Whiteness sets off colored pen barrels.

**BAKELITE Brand Styrene Plastic** permits a range of styles, sizes, and colors for these flower pots and planters and their saucers. Glossy surfaces are unaffected by gardening substances.

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All these advantages work for you—the guidance of Bakelite Company representatives backed by extensive research and development facilities . . . prompt delivery and service from strategically located plants and warehouses . . . more than 46 years of experience in the plastics field. Put them all to work now. Typical results are shown by the examples above.

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# U.S.I. POLYETHYLENE PROCESSING TIPS

Vol. 1, No. 5

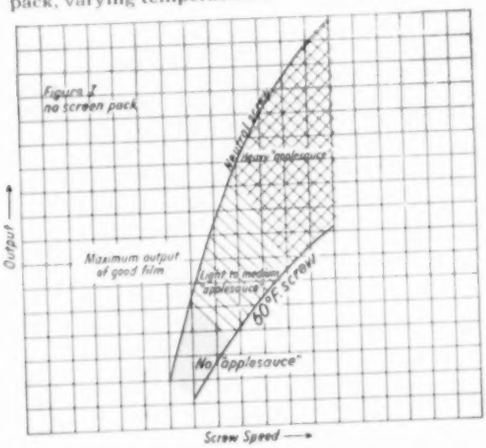
## IMPROVE FILM APPEARANCE

If operating conditions are not quite right when polyethylene film is being extruded, the result is sometimes a pebbled, wavy structure which looks like applesauce. This "applesauce structure" is bad for two reasons. It not only gives the film a poor appearance, but also results in poor tear strength and lower impact resistance.

The problem: how to eliminate "applesauce structure" and still get maximum output. The solution: run a neutral screw (no cooling) at high speed, and use a heavy screen pack. The effects of these variables were studied in tests run with a 2½" electrically heated extruder having a 13 to 1 L/D ratio.

### Neutral Screw Gives Best Results

To determine the effects of screw temperature independent of screen pack, U.S.I.'s technical service engineers ran a series of tests with no pack, varying temperature from neutral to 60° F.

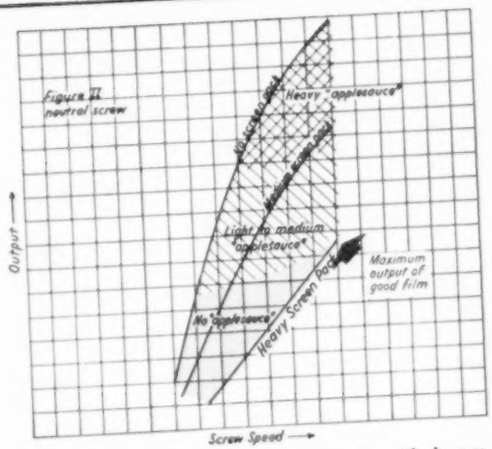



Film output at various screw speeds and temperatures with no screen pack. Only the two curves for neutral and 60° F screws are indicated, although several runs were made in between.

As you can see from Figure I, "applesauce structure" is heavy when output and speed are high, gets lighter and finally disappears as screw speed and consequently output are reduced. It is evident, however, that you get the highest output of satisfactory material when running with a neutral screw.

### Heavy Screen Pack Increases "Applesauce"-Free Output

Having determined that a neutral screw gives best results, U.S.I. engineers then maintained that condition while studying the effects of various screen packs.




Film output at different screw speeds with heavy, medium and no pack, using neutral screw.

You can see from Figure II that the heaviest pack allows the greatest output of satisfactory film, although screw speed must be high to accomplish this.

By comparing Figures I and II it becomes evident that when you use a neutral screw, simultaneous use of a heavy pack can permit an output of quality film about 30% higher than that obtained with no screens, other conditions being the same.

### U.S.I. Makes 3 Film-Grade Resins

These tests were run by U.S.I.'s technical service engineers, to help users of U.S.I. PETROTHENE® polyethylene resins make the best possible film for their customers. U.S.I. film-grade resins include:

PETROTHENE 110 and 210 — tailormade for blown and flat film extrusions. Degree of slip can be tailored to customer requirements.

PETROTHENE 213 — selected in specific cases for transparency, hand and high production rates.

### U.S.I. Offers Technical Assistance

Because of space limitations, this has been only a brief discussion of the problem of getting the maximum output of film consistent with good appearance. However, U.S.I.'s technical service engineers have studied it in detail and will be glad to work with you on this or any other film extrusion problem you may encounter.

*Send for PETROTHENE TIPS file folder.*

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Special Hose Assembly Solves One-Man Helicopter Design Problem

By using a specially-engineered hose assembly, manufactured from a fluorocarbon resin tube and jacketed in stainless steel wire braid, Gyrodyne Company of America, St. James, Long Island, was able to solve a difficult design problem in developing a portable, one-man helicopter for the U.S. Marine Corps.

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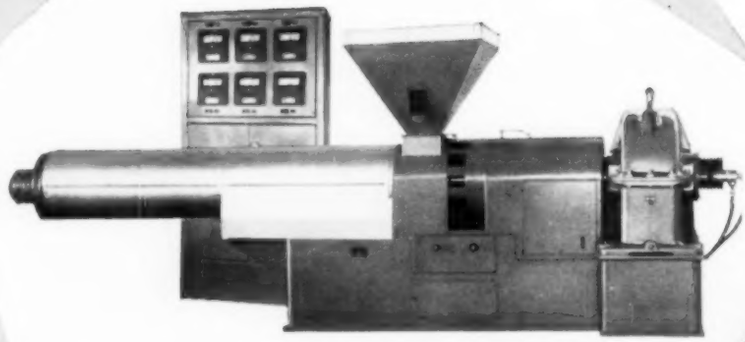

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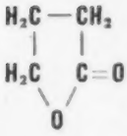

f.p. −44°C, b.p. 204°C, flash pt. 209°F. Soluble in water, alcohols, benzene, etc.

**SOLVENT:**
for polyacrylonitrile, cellulose acetate, polystyrene, shellac, etc. Selective solvent for acetylene in gas streams. Solvent in paint removers and petroleum processing.

**OTHER USES:**
Chemical intermediate for aliphatic and cyclic compounds. Cellulose acetate swelling agent for films and fibers.

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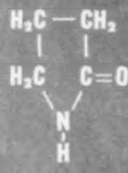

m.p. 25°C, b.p. 245°C, flash pt. 290°F. Soluble in water, alcohols, benzene, etc.

**SOLVENT:**
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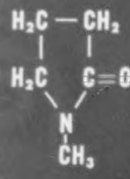

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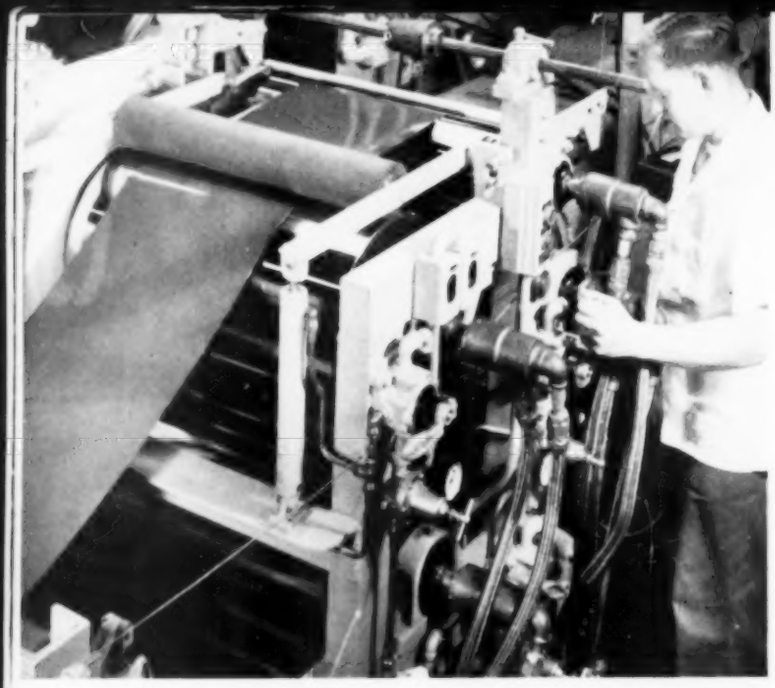
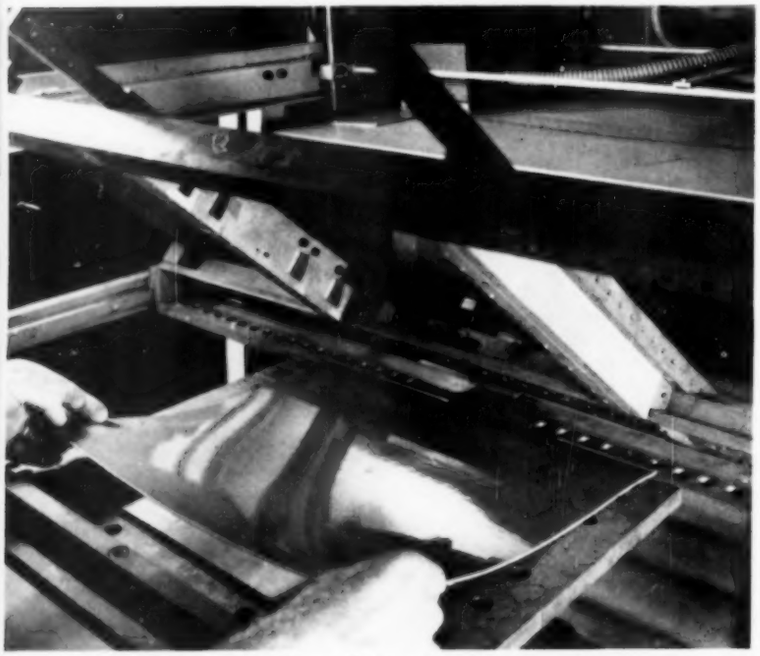
*From Research to Reality*

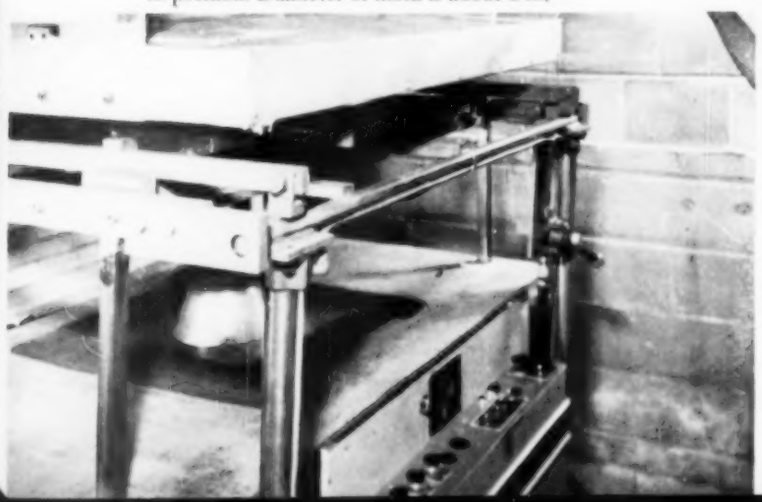


A view of experimental take-off machine with sheet emerging.



Placing polyethylene sheet in clamping frame of vacuum-forming machine.

Heater drawn forward over polyethylene sheet, with bowl mold in position. Diameter of mold is about 8 in.



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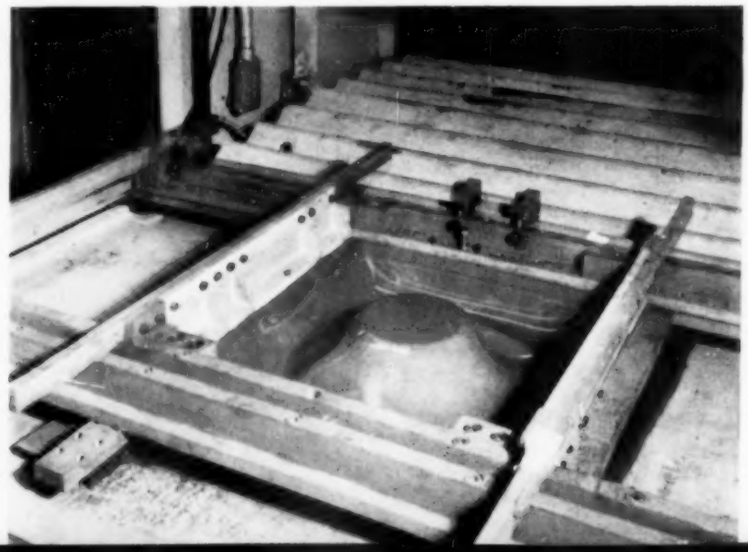
# Two superior extrusion materials for vacuum-forming

## New BAKELITE Brand Polyethylene Compound DFD-4030

DFD-4030 possesses these natural advantages for sheet extrusion and for vacuum-forming:

1. Compounded specifically for these processes.
2. Has melt index of approximately 2.0, indicating good resistance to stress cracking and freedom from skinning and chatter marks.
3. Permits continuous, in-line production where sheet extruder is connected to vacuum-forming machine.
4. Achieves a superior gloss and finish.
5. Permits complete dispersion of colorants and the elimination of streaking.

Draping heated polyethylene sheet over bowl mold as clamping frame descends before vacuum is applied.



Fitting plastics materials to their fabricating techniques in order to achieve maximum production efficiency is part of a continuing program at Bakelite Company. Pictures on these pages, taken at the Extrusion Development Laboratory at Bound Brook, N. J., show some of the test methods used there in processing both polyethylene and impact styrene sheets for vacuum-forming. This pioneering work with polyethylene is typical of the investigations being undertaken.

As a result of this activity, Bakelite Company has accumulated a fund of information on these materials that will benefit fabricators and end-users alike. It is readily available to you through the services of qualified Bakelite Company representatives.

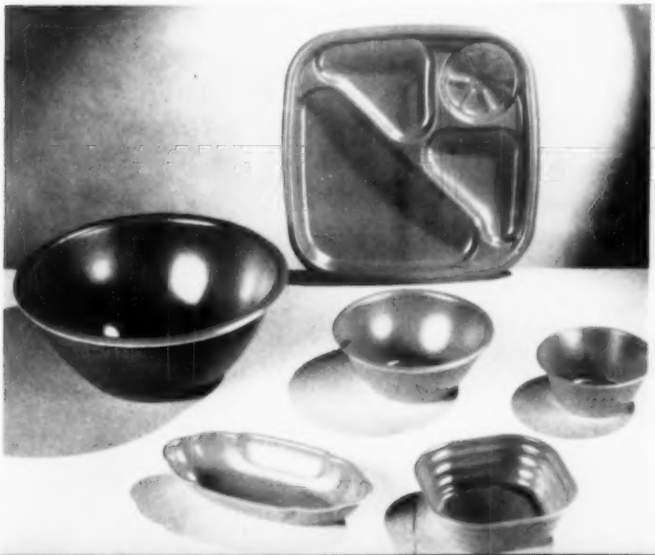
Styrene sheet retains the high gloss it exhibits here as it emerges from take-off machine.

## BAKELITE Brand Impact Styrene Compound TGD-5001

This companion to the new polyethylene, is already well established as a result of these features:

1. Offers the highest gloss yet attained in an impact styrene for extruded sheet.
2. Takes on permanent high gloss as it comes from the extruder—post finishing is not essential.
3. Retains gloss throughout deep drawing operations because it is not subject to plastic memory effect.
4. Exhibits sufficiently high heat-stability to permit recycling through the extruder.

Strength in thin sections afforded by TG-5001 makes these dishes and trays a useful addition to the modern kitchen. Note superior gloss!



For information on the properties and uses of BAKELITE Polyethylene DFD-4030 and Impact Styrene TGD-5001, write Dept. SZ-171.

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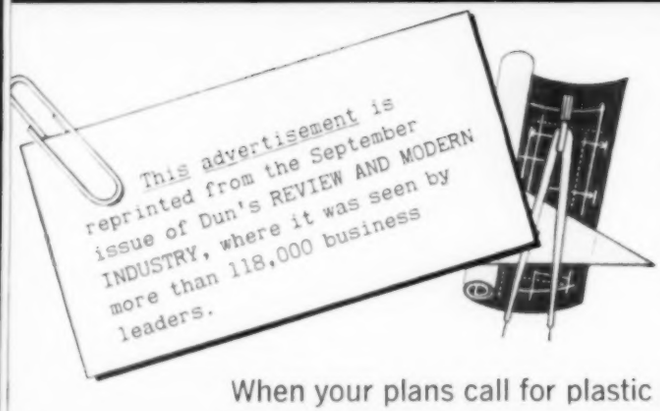
# Craftsmen of the 20th Century

No. 19 of a series to introduce you to some of industry's outstanding plastics craftsmen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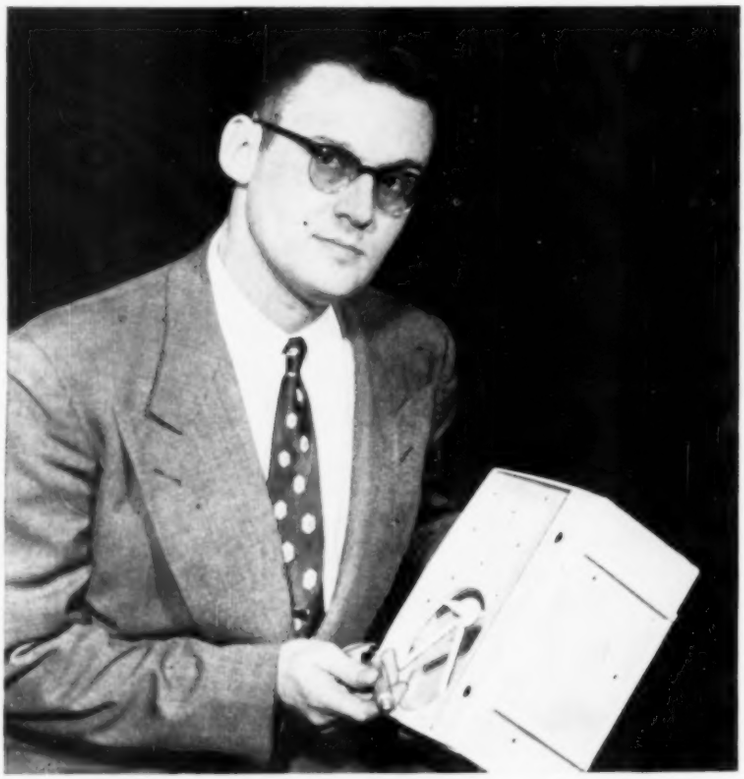
The artisan has traditionally been moved by the desire to master a material. In the old days the inspiration came from gold and silver, steel and stone. Today, new materials are at hand—but the challenge has not changed. The same priceless skills are now working with the fabulous family of plastics to produce articles by the million that can serve every industry, every home.

Two of these 20th Century craftsmen are pictured on this page. Monsanto, a major producer of high-quality plastic materials, salutes these men who are helping to mold America's tomorrow.

## When your plans call for plastic parts or products, consult an expert custom molder



**Robert H. Hoehn, Mack Molding Company, Wayne, N. J.** There are complete tools to produce approximately 3000 different plastic molded parts at Mack Molding's Wayne plant. Mr. Hoehn has been responsible for the design of a great many of them. Chief Engineer at Mack for the past 10 years, Bob at 36 is one of the youngest old-timers in the Plastics Engineering field. He currently is responsible for Cost Estimating, Tool Design and Procurement, Product Design and Molding Equipment Design activities at Mack. During World War II, Bob was responsible for the production of the famous M-52 plastic fuse used by Army Ordnance in Mortar shells. More recently he has assisted the country's leading manufacturers in the design of plastic components for the Refrigeration, Packaging, Radio & Television Industries. His most recent development is a 200-ton automatic molding machine that ejects finished molded articles completely ready for delivery to the customer. Vice President of the Newark, N. J. Chapter of S.P.E., Mr. Hoehn has authored several valuable papers on complex plastic molding problems for leading plastic technical publications.

**Mr. Leslie H. Cone, Diemolding Corporation, Canastota, N. Y.** Twenty-seven years ago, Leslie Cone joined Diemolding Corporation as a draftsman. Today he is Chief Engineer responsible for the conception of each molding job.

Says Mr. Cone, "Deciding on the most economical size, type and design of the mold to satisfy the customer is a major job. We know, for example, that production requiring a cored hole on the side of about ¼" diameter would most economically be produced by the transfer method. But many other questions can be answered only through tests and constant experimentation." Production of molded parts for airplane ignition and ordnance, as well as a wide variety of cooking utensils, calls for molds that may cost up to $30,000. Tolerances of .002 are not unusual.

Mr. Cone feels that "the plastics field has hardly touched the surface of its potential. With the continued improvement of materials and molding techniques, plastics promise to soon be an integral part of fields not even considered today."

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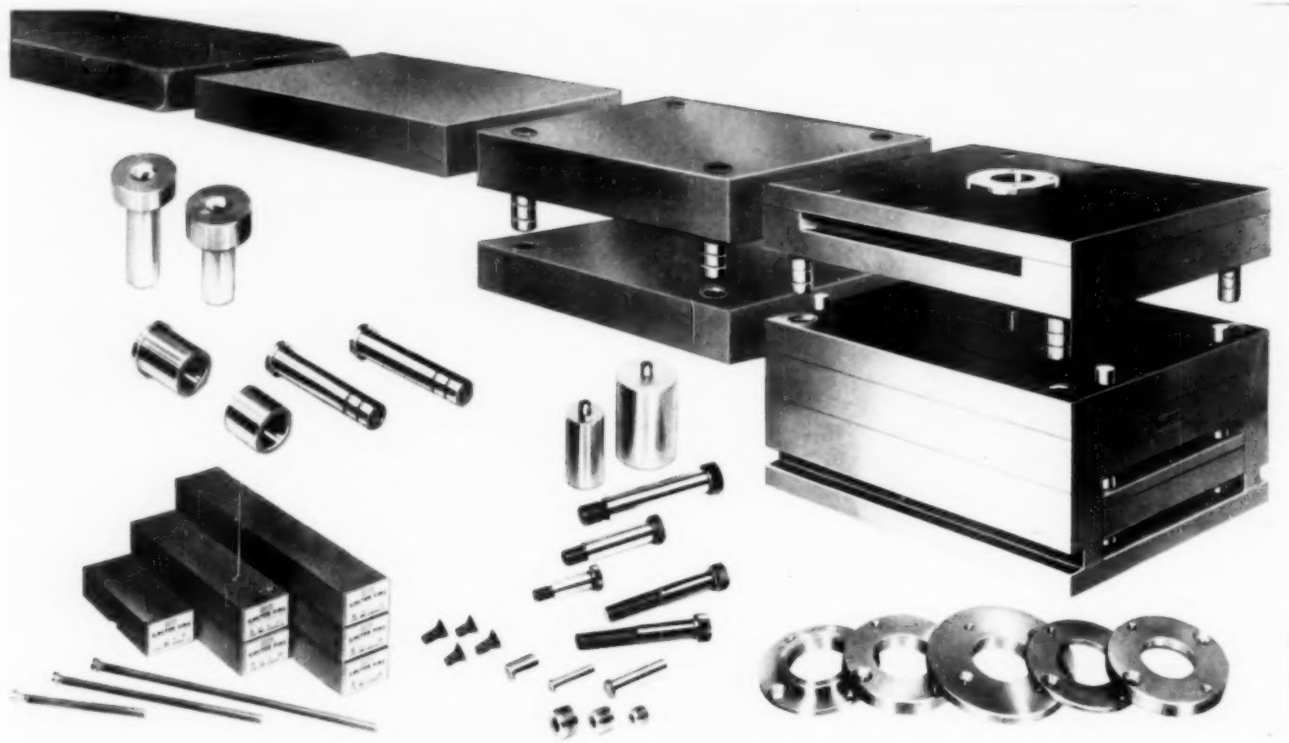

# PROGRESS THROUGH STANDARDS

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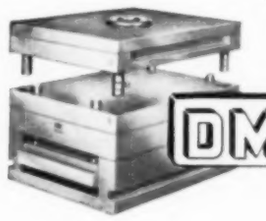


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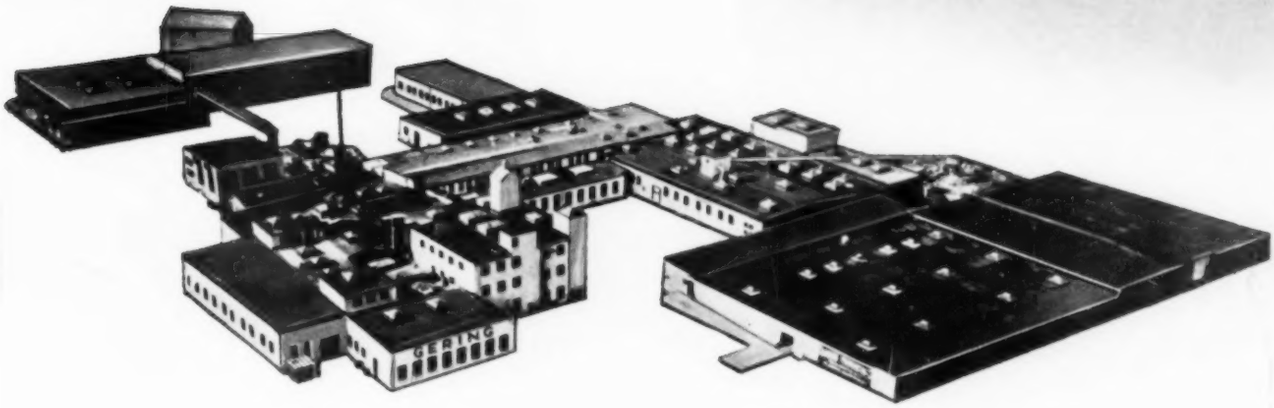


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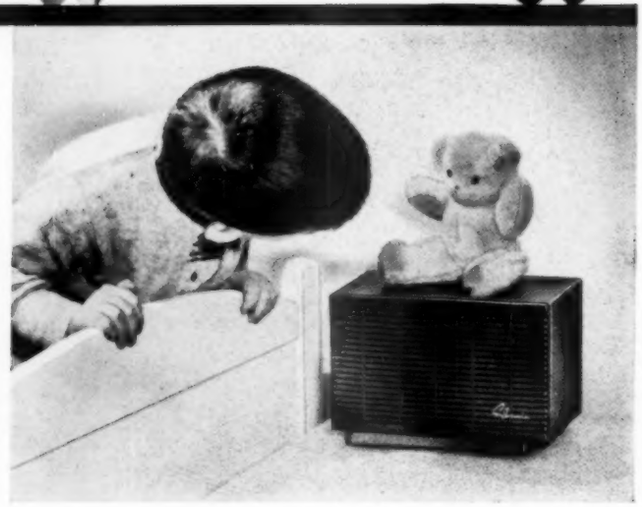

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# Measuring the Effect of Plasticized Vinyls . . .

# . . . On Impact Polystyrene

R. R. Dixon

*Westinghouse Electric Corporation*

**In the construction** of a refrigerator door the plastic inner panel is attached to the steel outer panel by screws. The tail of the refrigerator gasket is placed between the inner and outer panels to assure that the door is air-tight. Vinyl gaskets, having superior aging properties, have been used for some years, and impact polystyrenes have been used for inner door panels for almost five years. This means that polystyrene is used in intimate contact with a plasticized vinyl.

It was recognized in the beginning that improperly compounded vinyls could cause severe etching and marking of the styrene, but this condition was minimized by the development of vinyl compounds which would not mar polystyrene when placed in contact under accelerated storage conditions. Indeed, this type of test apparently is still of some value for some applications.

A screw driven through the plastic panel, the gasket tail, and the steel flange of the door pulls the polystyrene panel down tightly against the tail of the gasket. The panel bows up between the screws, and the rear surface of the panel is in tension at the screws. Various papers on the crazing of polystyrene have shown that a tensile load is required for crazing. Not only were these areas in tension, but they were also in intimate contact with the vinyl gasket. Since such a condition could lead to physical degradation, it was felt that the proper test would be one which would simulate the conditions of assembly.

The test which was evolved at the time was as simple as that. A small section of a door was assembled, using the test gasket. After three weeks exposure at 140 F the section was disassembled and the impact grade polystyrene was examined on the rear surface while a tensile load was applied by flexing the panel.

From this test it was found that marring and crazing are not related; severe crazing can exist with minor marring, and vice versa.

Although this test served a worth-while purpose, it was a long-time test, not good for control in high and judgment had to be used in evaluating materials. It was a long-time test, but not good for control in high volume production. And it was felt by some that it was not reliable because of variables in the system. Work was then started to develop a quantitative, short-time, more reproducible test.

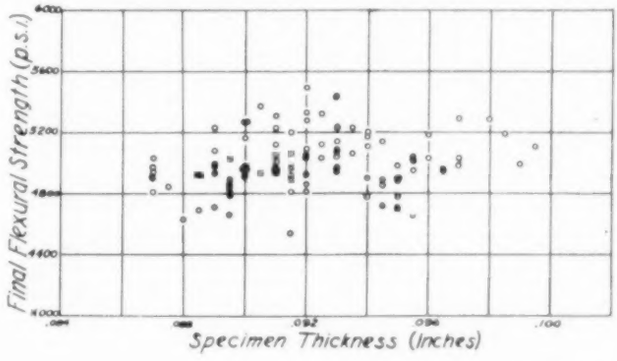
In essence the problem was approached by measuring the flexural strength of polystyrene after it had been stressed and exposed to the vinyl compound. To minimize the effect of molded-in stress, which might have been important in the injection molded panel used in the test described above, extruded polystyrene sheet was used. Originally, tests were made in the direction of extrusion and perpendicular to this direction. Most of the work was done parallel to the extrusion direction and these data are reported here. Sheets about .100 inch thick were used, and most of the data reported here are from a single large sheet. To eliminate variables caused by methods of attaining gloss on the front surface, only the rear dull surface was considered.

Impact polystyrene specimens ¾" x 5½" were cut with a circular saw. Each was wrapped over a 7" radius jig and was taped to the jig at the ends. The specimen was then placed on a flat piece of vinyl gasket material and was forced against it by tightening a ¼" number 20 bolt to 20 inch-pounds torque against the jig. The assembly was then aged a specific length of time at a constant temperature. After exposure, the sample was removed and allowed to cool to room temperature before testing.

Flexural testing was conducted according to A.S.T.M., D790-49T, using a span of 1.0 inch and crosshead motion of 0.05 inch per minute. Maximum stress attained was reported. In each case five specimens were tested to obtain an average.

The procedure having been established, the next step was to control the conditions. The 7" radius jig was held within ± .002 inches as a practical machining tolerance. A piece of polystyrene .100 inches thick wrapped over this radius has an elongation of 1.43%. For a thickness of .090 inches the elongation is 1.29%.

Figure 1. Flexural Strength as a function of thickness.




*This paper was presented at the Twelfth Annual SPE Technical Conference.*

Since the amount of elongation has been shown to be an important variable in such a crazing test, it was necessary to find how much tolerance in thickness should be allowed. To make this study one hundred and twelve test values were used. Since they were the results from tests on various gaskets, the averages of each five values were reduced to an arbitrary value of 5000 p.s.i. The individual values were then corrected to this basis and were plotted as a function of the thickness of the specimens (Figure 1). From these data there was obtained a statistical correlation coefficient, which expresses the relationship between final flexural strength and specimen thickness. For there to be a significant relationship for this number of samples the correlation co-efficient must be about 0.18; actually it was only 0.028, indicating no correlation over a thickness range of .087 to .100 inches.

TABLE I

Polystyrene Flexural Strength After Gasket Exposure

| Gasket | Flex. Str. p.s.i. | % Retention | Standard Deviation |
|---|---|---|---|
| a | 5290 | 40.4 | 320 |
| b | 5740 | 43.9 | 130 |
| c | 6040 | 46.1 | 140 |
| d | 6190 | 47.3 | 100 |
| e | 6390 | 48.8 | 220 |
| f | 6560 | 50.1 | 290 |
| g | 6690 | 51.1 | 300 |
| h | 6740 | 51.5 | 160 |
| i | 6860 | 52.4 | 190 |

Later data for one gasket material on various thicknesses of sheet gave, with only 24 samples, a correlation coefficient of 0.26 over a range of .080 to .105 inch thickness; a value of 0.40 is required for a significant correlation (Figure 3). The coefficient being positive means that if there is a slight correlation, it is in such a direction that the thicker specimens maintain more strength in spite of the more severe exposure condition. Tests using these same materials, but measuring perpendicular to the extrusion direction, gave a very definite correlation (Figure 2). The coefficient in this case was 0.93 for the .080 to .105 inch range.

The range for the parallel samples should not be extended without verification because it was shown that at zero thickness (infinite radius) there was no decrease in flexural strength from the original unexposed sample.

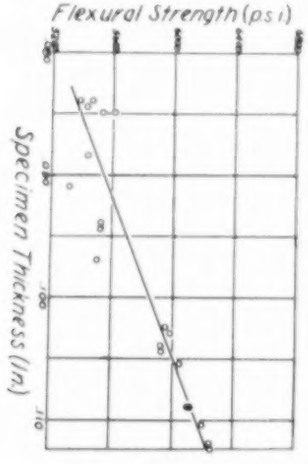



Figure 2

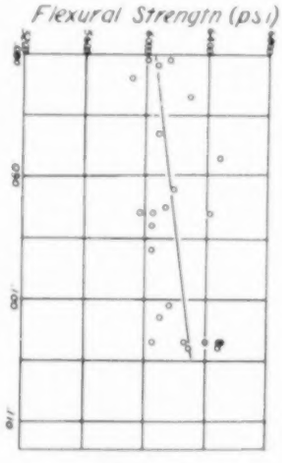



Figure 3

TABLE II

Comparison of Sheets by Per Cent Retention

| Gasket | Sheet A Parallel | Sheet A Perpendic. | Sheet B Parallel | Sheet B Perpendic. | Sheet C Parallel |
|---|---|---|---|---|---|
| a | 51 | 58.9 | 60.5 | 61.8 | 50.3 |
| b | 51.7 | | 60.7 | | |
| c | 52.4 | | 59.4 | | |
| d | 43.2 | 52.9 | 53.7 | | |

The temperature chosen was 90°F, and the allowable tolerance has not been determined. For these tests the temperature varied less than one degree; it probably should be held to plus or minus two degrees.

In the early stages of this development the time of exposure was 24 hours; however, it was found that two hours was sufficiently long for the test. No comprehensive study was made on effect of exposure time, but indications were that the degradation was a logarithmic function of the exposure time. Plus or minus five minutes would be a reasonable tolerance.

Results of the first tests on various vinyl compounds are shown on Table I. It was assumed that the final strengths would be a percentage of the original strength, and these percentages are listed. Note the results on samples f, g, and h; these are all the same vinyl compound and show the reproducibility of the test. Since the data in Table I were all taken on one sheet of polystyrene, supplementary values were measured on sheets from other extruders. These data are listed on Table II.

In examining Table II note that the results, when listed by per cent of retained strength, are not consistent. Values in the first and third columns should be comparable and are not. Values in columns two, four, and five should also be comparable and are not. It therefore appeared that such an evaluation was not valid. The same results when tabulated as final strengths became quite consistent. Note in Table III, that columns one and three are now very similar, as are columns two, four and five. One explanation for such a condition would be the existence of a skin; an experiment designed to show such a skin proved that there was none.

TABLE III

Comparison of Sheets by Flexural Strength (p.s.i.)

| Gasket | Sheet A Parallel | Sheet A Perpendic. | Sheet B Parallel | Sheet B Perpendic. | Sheet C Parallel |
|---|---|---|---|---|---|
| a | 6560-6740 | 6430 | 6660 | 6410 | 6460 |
| b | 6770 | | 6680 | | |
| c | 6860 | | 6530 | | |
| d | 5660 | 5750 | 5910 | | |

When this test was extended to a large list of extruders' materials, using one gasket material, it was found that the final flexural values were not so consistent as was indicated in Table III. Material from each sheet supplier was consistent, but among suppliers there was a fairly broad range of results. See Table IV. When the percentage of retained strength was plotted against original flexural strength, it appeared that the percentage dropped off as the flexural strength increased (Figure IV). Figure IV is plotted with the best straight line and with lines at a distance of plus and minus 2 sigma (which would include 95% of all points). This same information on a retained strength—original strength plot is shown as Figure V. From this curve, it is evident that in the 11,000 to 13,000 p.s.i. range of sheets used for the data in Table II, re-

(Please turn to Page 40)

# Polyurethane Foams

C. J. Harrington
*E. I. du Pont de Nemours and Co., Inc.*

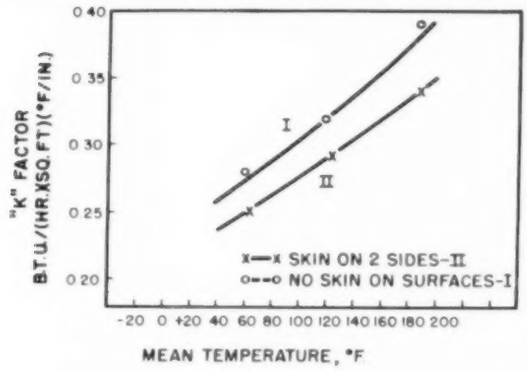
THE BASIC INGREDIENTS of the polyurethane foams are diisocyanates and polyols. These are chain extended by reacting with a small amount of water. During the series of reactions involved, carbon dioxide gas is liberated. If the original viscosity of the polyol is favorable, and if the chain extension increases the viscosity at an appropriate rate, this carbon dioxide gas is trapped in the gel structure just as it is in the rising batter of a cake. If suitable catalysts have been employed, the resulting foam cures to a stable, solid state.

It seems apparent that the length of the polyol chain and the degree of branching in it will have a definite effect on the type of foam produced. Indeed, this turns out to be the case. Long, straight chain diols of from 1500 to 3000 molecular weight give elastic or rubber-like foams. Combinations of glycerine, castor oil or other polyol and polyisocyanates produce foams which are quite rigid.

The amount of carbon dioxide released in the foaming step determines the density of the foams. The amount of carbon dioxide and thus the density of the foams, if allowed to foam without restraint, can be controlled by the amount

Figure 1

THERMAL CONDUCTIVITY VS. MEAN TEMPERATURE




of excess isocyanate and the equivalent water used in the formulation. Thus, foams can be made ranging in density from under 2 pounds per cubic foot to over 20 pounds per cubic foot.

The ability to control rigidity or resilience and density to almost any desired degree is one of the significant features of the polyurethane foams. In the future it seems likely that there will be a whole series of foams of widely varying properties.

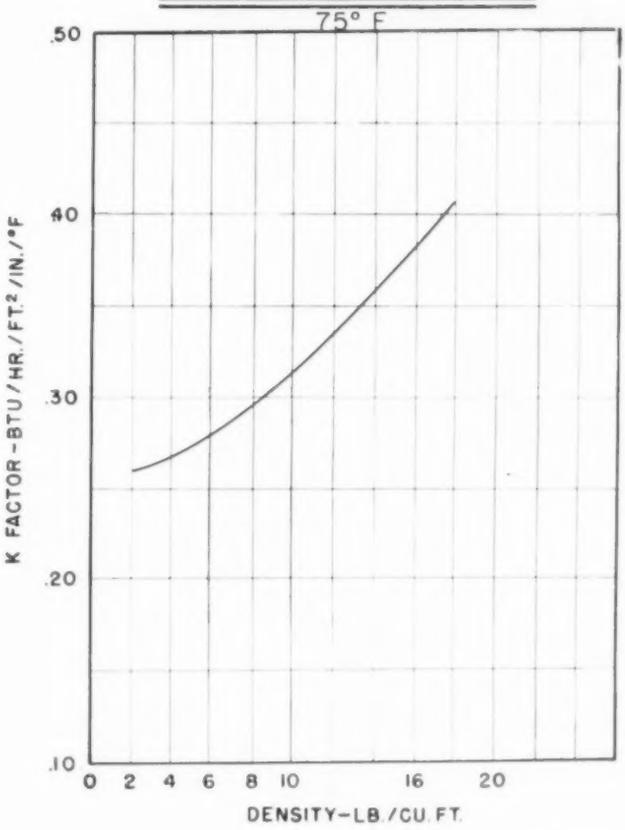
There are, however, two main types of foams which can be classified as to use; the rigid or semi-rigid insulating foams and the resilient cushioning foams. It is these two main classes that are to be considered at this time.

As low temperature insulation, the semi-rigid foams have a good K factor, as is shown in Figure 1, which is a graph of thermal conductivity vs. temperature for a typical castor oil based foam. The insulating value is the equivalent of that of cork and better than that of some other low temperature insulators commonly used.

It has been possible to achieve densities as low as 1 pound per cubic foot when machine-made mixtures are allowed to foam in large volume. If the cavity to be filled is small, or if the volume to surface ratio of the cavity is unfavorable, the density of foam obtainable will be somewhat greater, but it should be possible to count on a den-

Figure 2

POLYURETHANE FOAM
THERMAL CONDUCTIVITY




*This paper was presented at the Twelfth Annual SPE Technical Conference.*

sity between 1.5 to 2 pounds per cubic foot. The thermal conductivity is relatively independent of density, so the main advantage resulting from low density is cost. Figure 2 charts density vs. K factor at a given temperature.

At a density of 2 pounds per cubic foot, the volume cost of the polyurethane foams will be equal to or less than many of the now used low temperature insulations, but it is unlikely that they will approach such materials as rock wool or fiber glass in basic material cost.

It is obvious, however, that basic material cost is not the only factor and that any solid insulator in the form of special shapes becomes considerably more expensive. Also, the labor cost of actually installing the insulation is a very significant factor in the final cost.

What has created a lot of interest in the urethane foams as insulation is the ability to mix two liquids together and to pour them into place in molds made of paper or the like. The insulation of complicated valve assemblies becomes in this way quite a simple job. These foams can also be sprayed in thickness from ½ inch up to 2 inches or more, even on overhead surfaces.

Obviously, either spraying or the pouring of liquids promises considerable economy where it is necessary to form the insulation into special shapes, in pipe covering, for example, or where considerable labor is required in the application to the job.

However, the ultimate potential for the rigid urethane foams will not be realized until full advantage is taken of the contribution the foams can make to the physical properties of laminated structures.

In insulated transportation equipment, it is generally necessary to install some sort of bracing to hold conventional insulation in place and to hold inner and outer shells or walls together. This bracing is expensive to install and is a source of heat loss. The polyurethane foams can be poured in place to act as insulation and because of their excellent adhesion to metals as a part of the structure, make bracing unnecessary and in some cases permit the use of lighter gauge metals. Figure 3 shows the bond strength of a typical castor oil based polyurethane foam to

Figure 3

BOND STRENGTHS
OF POLYURETHANE FOAMS

| Foam Density, Lb./Cu. Ft. | 2 | 5 | 10 | 20 |
|---|---|---|---|---|
| Bond Strength, Psi | | | | |
| To Aluminum | 10 | 27 | 56 | 158 |
| To Glass | 9 | 25 | 50 | 142 |
| To Steel | 12 | 29 | 62 | 146 |
| To Wood | 17 | 29 | 62 | 170 |

various materials. Figure 4 shows the corresponding tensile strength of the foam itself; Figure 5 gives the compressive strength vs. density at this same temperature, and Figure 6, the recovery from 50 per cent compression.*

This latter is of considerable importance in the transportation field since it indicates a degree of elasticity that permits considerable movement of the structure without damage to the foam or to the bond between the foam and the substrate. For very low temperature service, additional elasticity may be built in. The resilient foams have been tested at the temperature of liquid nitrogen and found not to be friable.

In the building industry where lightweight structural panels are increasing in demand, the polyurethane foams promise a cheap method of making laminated structures out of metals or plastics which combine insulation, sound deadening, and rigidity in one package. Here, again, the ultimate economic potential of the foams will not be realized until a detailed engineering analysis is made of the finished laminate to make sure that full advantage has been taken of this opportunity to reduce metal gauge or to reduce the thickness of the panel over what might be possible with conventional materials.

The second main class of foams, the resilient cushioning foams, has to date received rather more attention than the insulating foams. In some ways, however, they are not

**The above properties can be improved considerably in special formulations.*

Figure 4

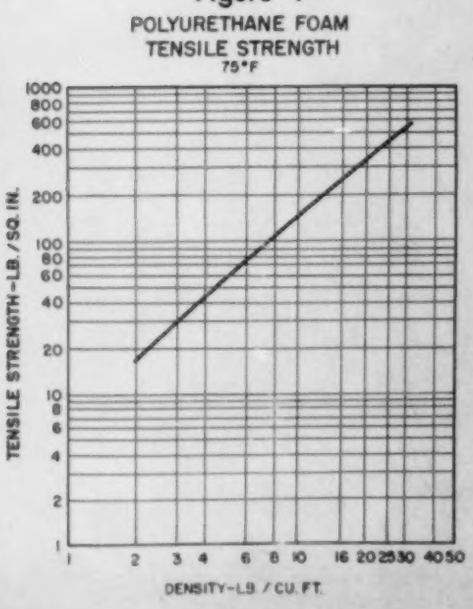



Figure 5

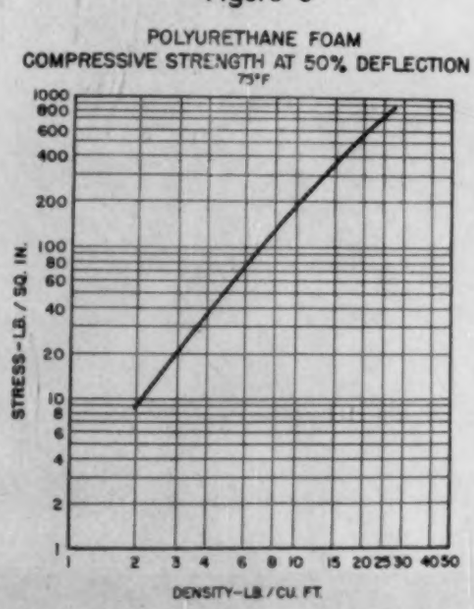
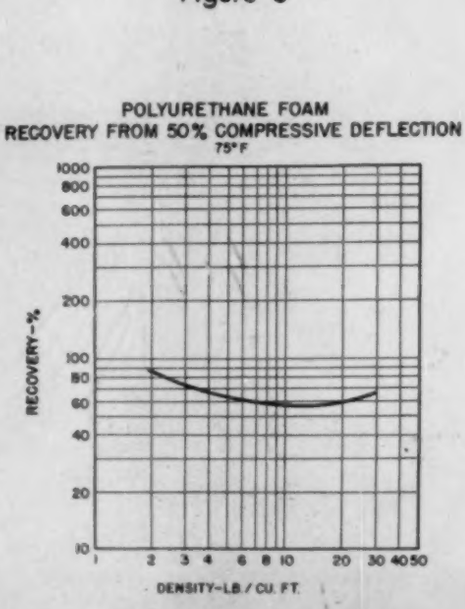



Figure 6



yet as far advanced technologically as the latter, at least in strictly cushioning applications. Most of the resilient urethane foam made now is produced as slab stock which is cut and trimmed to make the desired end product. While this may be a satisfactory method of manufacture for certain end uses, it seems on the face of it to be a step backward in foam technology.

Most of the polyurethane foams have, so far, lacked certain properties that are essential in seating or bedding although they appear satisfactory for uses such as automobile crash pads and certain clothing uses. The particular properties that have been lacking have been resilience and a load deflection curve comparable to rubber. The urethane foams have generally exhibited a so-called plateau in the deflection range most encountered in seating or bedding. This means that a person sitting on a urethane cushion first has to overcome a fairly stiff foam and then slowly drifts quite a distance into the cushion. Figure 7 shows this in comparison to foam rubber. In addition, the freeze resistance of currently available foams has not been adequate for transportation seating applications.

The conventional foams have heretofore been made from long chain polyester diols.

Within the past year, foams made from long chain ether glycols have become available on a small scale. They have a resilience almost equivalent to natural rubber and a load deflection for a 2 pound per cubic foot foam that very closely matches a 6 pound per cubic foot rubber latex foam. The freeze resistance is not quite equal to that of natural rubber but is much superior to the polyester foams and is believed to be acceptable for such applications as automobile seating. Figure 8 shows a comparison of the

Figure 7

COMPRESSION DEFLECTION CURVES

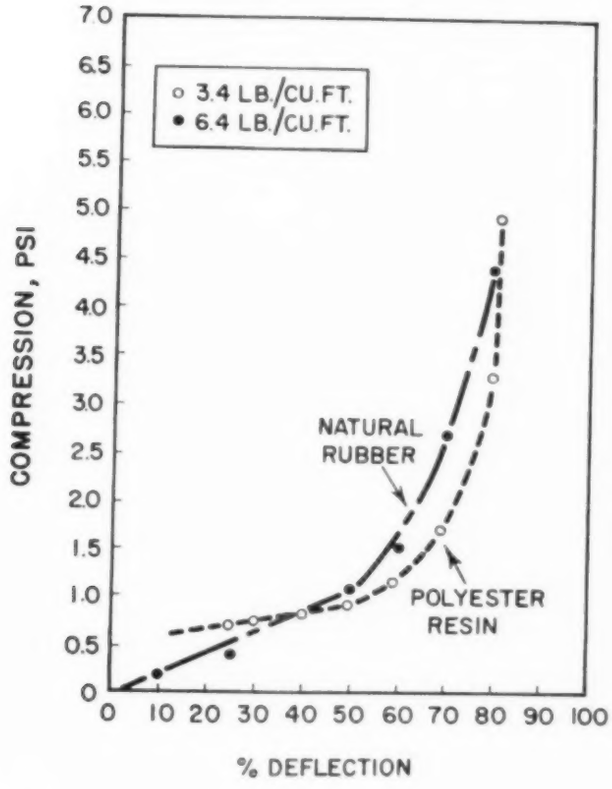

o 3.4 LB./CU.FT.
• 6.4 LB./CU.FT.
NATURAL RUBBER
POLYESTER RESIN
COMPRESSION, PSI
% DEFLECTION
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0
0 10 20 30 40 50 60 70 80 90 100

Figure 8

FREEZE RESISTANCE AT – 20°C

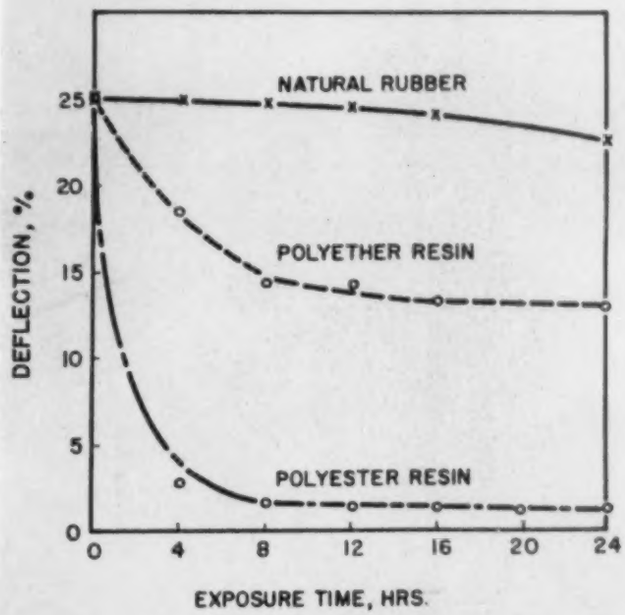



Figure 9

COMPRESSION DEFLECTION CURVES

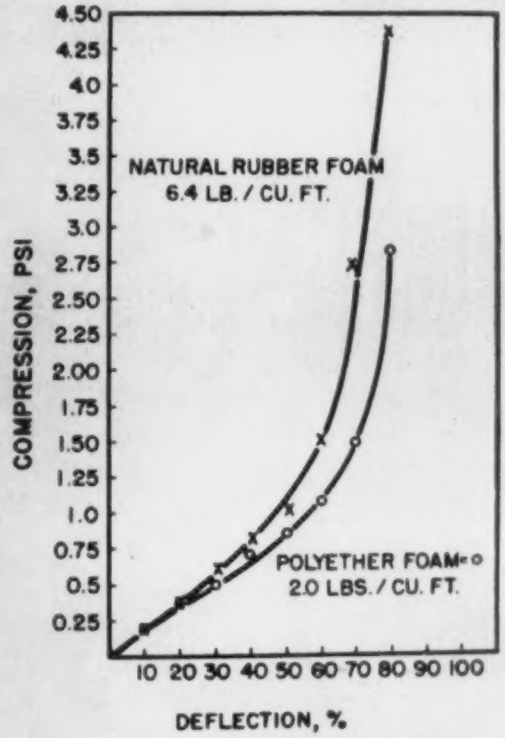
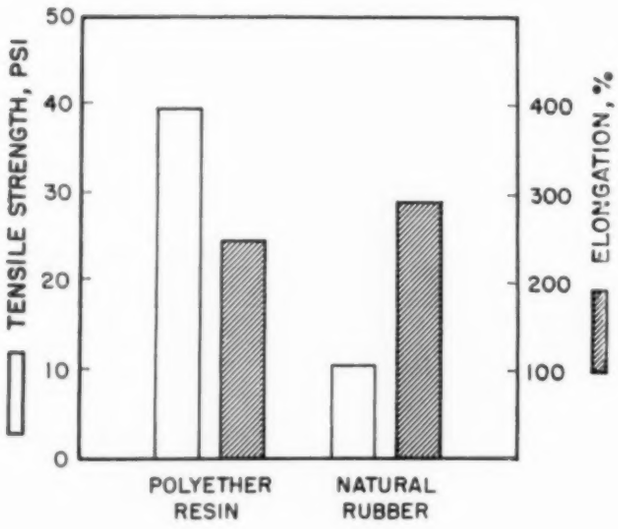


Figure 10

TENSILE AND ELONGATION PROPERTIES




three in this property. In most other physical properties, the ether foams are equal to or better than polyester foams. They have the high load carrying capacity at low density, the very superior tensile strength and solvent and oxidation resistance characteristic of all the urethane foams, which has made them potentially superior to other elastomeric foams for many uses. Figures 9, 10, 11 and 12 illustrate these properties.

The ether glycol foams are somewhat more complicated to process than polyester foams. They can be made successfully only by partially reacting the isocyanate and glycol as a separate step and then reacting this product with water and catalyst to produce the foam. This results in the necessity for handling quite viscous materials, which take special techniques.

However, one of the long range drawbacks of the urethane foams has been the inability to mold them into anything but very simple shapes. It has been possible on the other hand to mold the polyether foams into fully cored (7 inches deep) bus cushions and mattresses, in the laboratory. This core molding has not yet been reduced to commercial practice; so it is difficult to say what curing cycles and techniques will be involved, but the laboratory experience indicates that the total mold cycle will not be over 15 minutes. There is reason to believe that this can be further improved. Naturally, such core molding as has been done to date has been in rubber latex molds. It remains to be seen whether the type of coring that is best for rubber is what is wanted for urethane foams, and a detailed study of core design is certainly indicated.

While the molding of fairly intricate shapes seems to be a step forward in urethane foam technology over the trimming of slab stock, the resilient cushioning foams will probably not reach their ultimate potential until the foamed-in-place principle and their adhesion to other materials are fully utilized, just as in the case of the rigid foams. In principle, a seat cushion can be made by putting the fabric in the bottom of a mold and then pouring the foaming ingredients onto it. Just how much labor can be saved in sewing and fitting the fabric will certainly be an interesting study. Similarly, the economics of foamed-in-place rug backing, when the techniques are all worked out, should be an object of real scrutiny.

When in the not too distant future all of the application problems are worked out, there will be resilient polyurethane foams with the desirable cushioning properties of natural rubber foam at a volume material cost lower than any foreseeable for natural rubber or GR-S latex, and with a labor saving potential in fabricating composite structures which has only begun to be investigated.

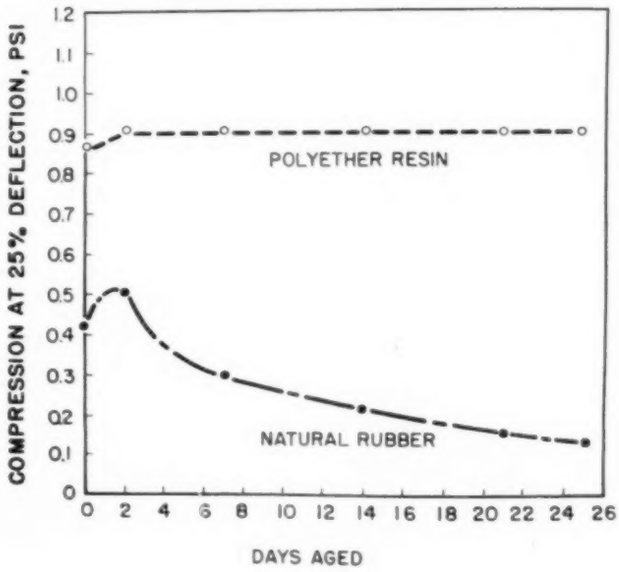
Figure 11

SOLVENT RESISTANCE OF POLYETHER AND NATURAL RUBBER FOAMS

| | Linear Increase, % | |
|---|---|---|
| | Polyether Resin | Natural Rubber |
| IMMERSED 24 HRS. AT ROOM TEMPERATURE | | |
| Petroleum Ether | 10 | 20 |
| Cyclohexane | 15 | 85 |
| Benzene | 40 | 135 |
| Carbon Tetrachloride | 34 | 135 |
| Carbon Disulfide | 33 | 38 |
| Ethyl Alcohol | 12.5 | 8 |
| Glycerine | 3 | 5 |
| Acetone | 24 | 6 |
| Nitrobenzene | 46 | 12.5 |
| Ethyl Acetate | 32.5 | 7.5 |
| Linseed Oil | 6.5 | 17.5 |
| Castor Oil | 10 | 7 |
| IMMERSED 48 HOURS AT 212°F. | | |
| Kerosene | 19 | 140 |
| Light Lubricating Oil | 19 | 92.5 |
| Medium Lubricating Oil | 6 | 82.5 |
| Heavy Lubricating Oil | 2.5 | 60 |
| Water | 2.5 | 3 |

Figure 12

EFFECT OF AGING IN OXYGEN BOMB



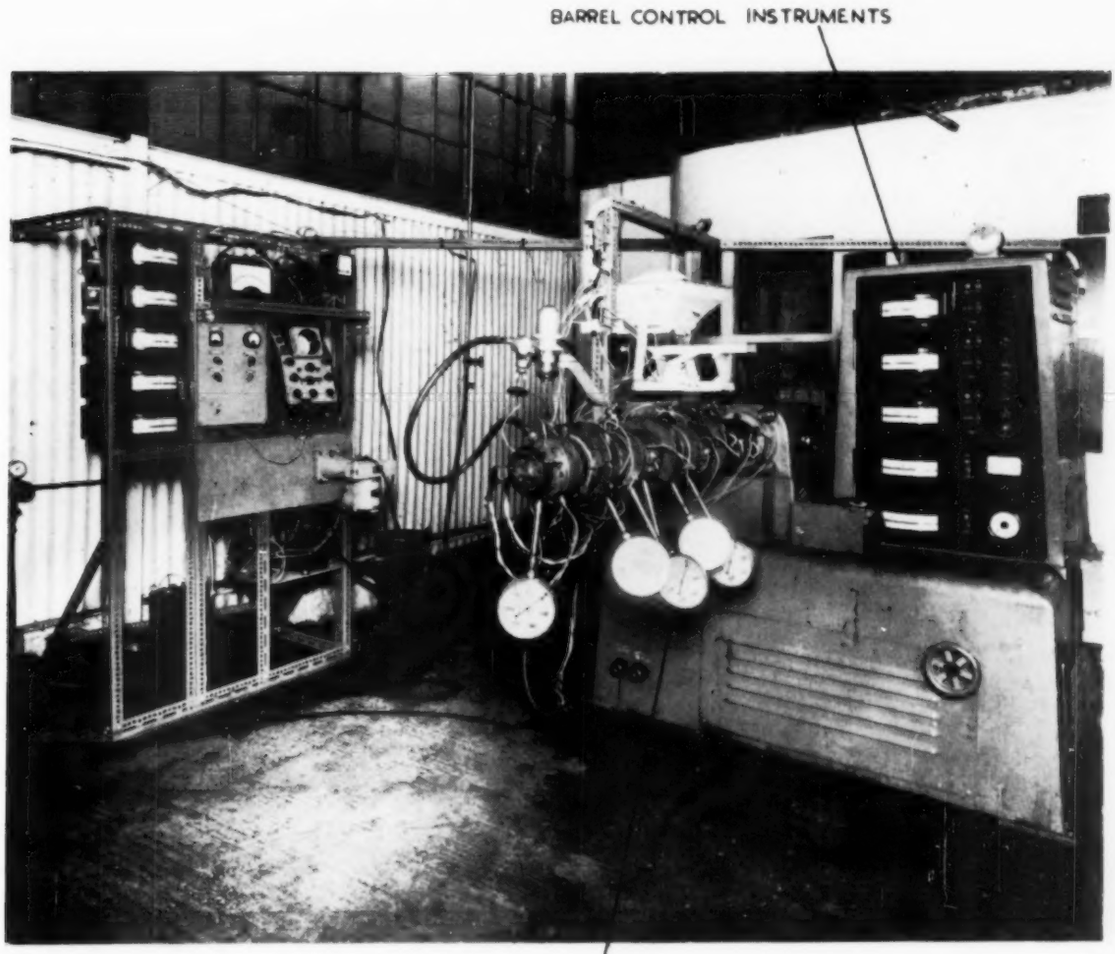



Fig. 1 Experimental Test Equipment

# Problems and Trends In European Extruder Design

E. Gaspar

*Projectile and Engineering Company*
*London, England*

The Projectile & Engineering Co. decided to produce a range of single screw machines. A series of experiments was decided upon to obtain information which would assist in the basic design of these machines. We posed ourselves the following questions:—

1. Over what speed range can a single screw machine be expected to operate?
2. How closely can adiabatic conditions be approached on a standard machine?
3. What effect do screw characteristics and die sizes have on these points?

*This paper was presented at the Twelfth Annual SPE Technical Conference.*

## Theoretical Basis

A great deal of theoretical work has been carried out in England by Rowell, Finlayson (2) and Rigby (3); in Switzerland by Maillefer (4); in the United States by the team of workers (5) at duPont and in Germany by Meskat (6), on the basic output and power relationships for a single screw machine. It was, therefore, possible to use much of this theoretical work as a basis on which to design the experiments mentioned above (7). In this way the theoretical conclusions were compared

with practical results and it was possible to estimate the extent to which theory was borne out in practice.

## Test Equipment

The equipment used in the experiment consisted essentially of a PECO 2½" extruder powered by a 15 h.p. constant speed electric motor, with an infinitely variable speed box and worm reduction gear. The barrel of the extruder was modified to accept six pressure gauges spaced at regular intervals along the extruder as can be seen in Figure 1. The heaters on the barrel were controlled in three zones and the die in two zones by standard potentiometer type pyrometers, which sensed the heaters by surface thermocouples. Deep thermocouples were provided at 11 points along the barrel and die. Four screws were used during the test and their general description is set out in the following table:—

| Screw | L/D Ratio | Compr. Ratio | Starts | Pitch | Depth of Flight At Met. Section |
|---|---|---|---|---|---|
| 1 | 16/1 | 4/1 | 1 | 2.6 | .140 |
| 2 | 16/1 | 2/1 | 1 | 2.6 | .250 |
| 3 | 16/1 | 2/1 | 1 | 3.0 | .250 |
| 4 | 16/1 | 2/1 | 1 | 2.6 | .250 |

Each of these screws was bored to enable cooling water to be passed through it and facilities were available to measure the rate of water flow and the ingoing and outgoing water temperatures.

A range of 5 tube dies was used, whose characteristics are set out in the table below:—

| Die | I/D | O/D | Land Length | Cross Sect. Area |
|---|---|---|---|---|
| D.1 | .375" | .75" | 1.50" | .331 sq ins. |
| D.2 | .625" | .813" | 1.40" | .212 sq. ins. |
| D.3 | .625" | .725" | .75" | .106 sq. ins. |
| D.4 | .625" | .665" | .30" | .040 sq. ins. |
| D.5 | .625" | .645" | .05" | .020 sq. ins. |

A 350°C. thermometer was used to determine the mass average temperature of the extrudate. Time quantities of the output were weighed. Throughout these experiments I.C.I. Polythene Grade 7 was used.

## Experimental Procedure

For each of the four screws used during the experiment, a series of pressure, temperature and power readings was taken at r.p.m. values from 20 to 100 at 10 r.p.m. intervals. The temperature of the extrudate was measured and five minute camera runs were taken to record the length of time the heaters were on during each experiment. The temperature and quantity of water entering and leaving the screw were also noted for each run. A series of different temperature settings was used along

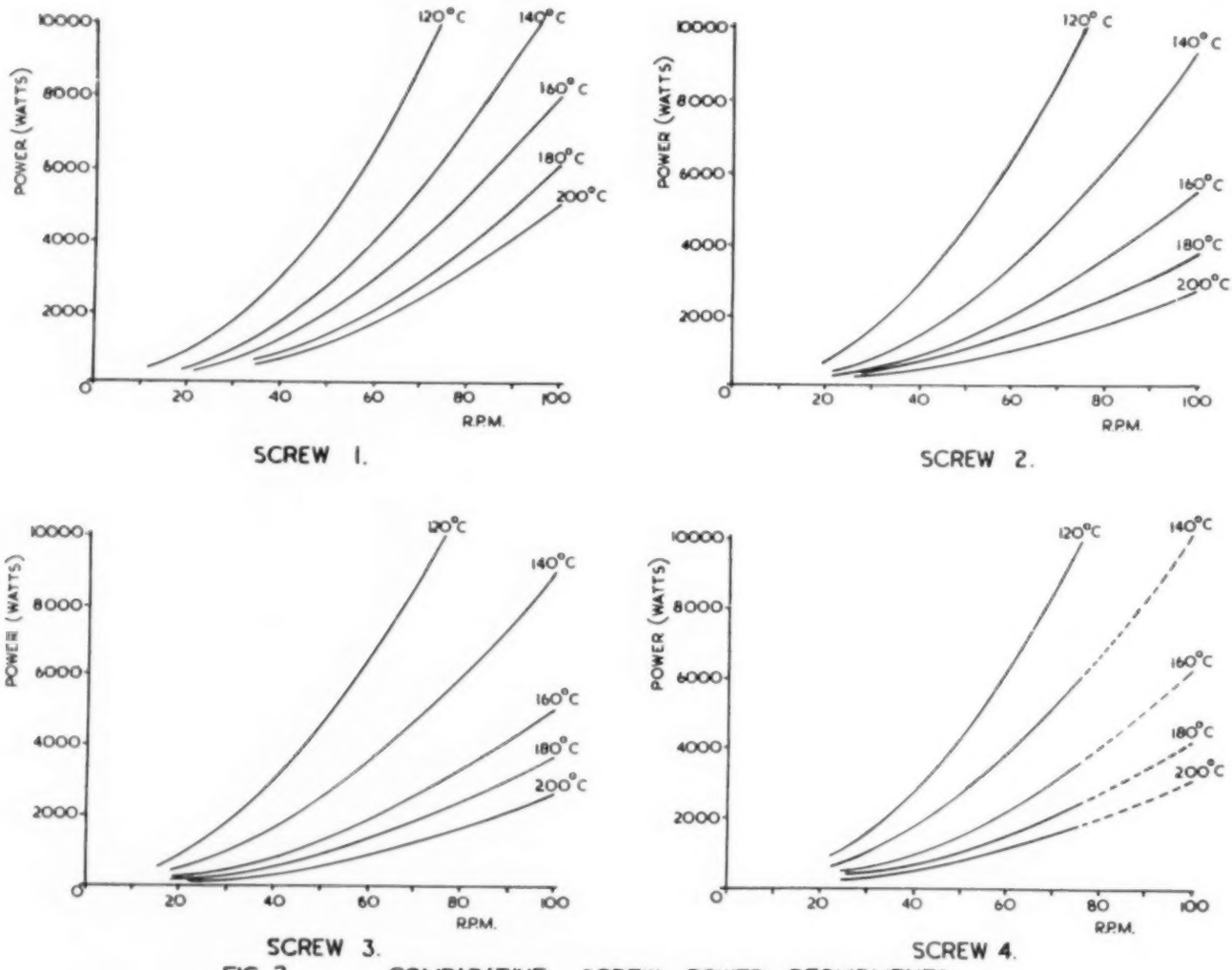



FIG. 2. COMPARATIVE SCREW POWER REQUIRMENTS.

the barrel in order to obtain a fairly wide range of heat inputs from the band heaters and the sequence of settings and recordings was repeated for each of the five tube dies and each of the four screws shown in the tables above. A series of pressure recordings was also photographed on the oscilloscope which was connected to a photo-electric pressure gauge at each of the pressure gauge stations. In this way, evidence was obtained of the way in which pressure fluctuates at various points along the barrel and of the effect that the screw speed has on these fluctuations.

## Experimental Results

The energy readings obtained from the wattmeter were modified by the overall efficiency of the machine drive and the amount of energy actually consumed by shear in the material was calculated. These energy values were divided out for each die and material temperature and plots of the type shown in Figure 2 were obtained. The curves shown in this diagram were obtained on die D.1 and tended to be exact parabolae, which could be expressed by the relationship $Z = aN^2$.

Since from this diagram the energy input by the screw for any r.p.m. with any material temperature is known, a more complete energy picture can be formed by constructing a diagram to show the energy content of the material coming out of the die and the energy in the cooling water on the screw. The energy balance of the whole system may be written as follows:

$$Z_s + Z_h = Z_m + Z_w + Z_r$$

where $Z_s$ = energy in by screw
$Z_h$ = energy in by heaters
$Z_m$ = energy out in material
$Z_w$ = energy out in screw cooling water
$Z_r$ = energy out by radiation, etc.

Since $Z_s$, $Z_h$, $Z_m$ and $Z_w$ are known, a full energy balance diagram may be drawn. Figure 3 is formed in the following manner: the line AB is the sum of $Z_m$ and $Z_w$ and the line CD is formed by subtracting $Z_s$ from $Z_m + Z_w$, thus the ordinates under CD show the amount of energy put into the material by the heaters. The line EF shows how much heat is actually given by the heaters and the difference between EF and CD shows the heat dissipated in radiation, i.e., $Z_r$. The point at which CD cuts the r.p.m. axis indicates the r.p.m. at which the extruder may be considered adiabatic. It must be appreciated, however, that heaters are still necessary until the point F, but from D to F they merely act as insulators. At r.p.m. values greater than F the heaters never come on and can, of course, be dispensed with, the extruder being completely adiabatic in the greater than F, r.p.m. range.

From diagrams of this type it is possible to obtain energy values which allow efficiency curves to be drawn. If we take the overall thermal efficiency of the system to be given by $E = 100\ Z_s/(Z_s + Z_h)$

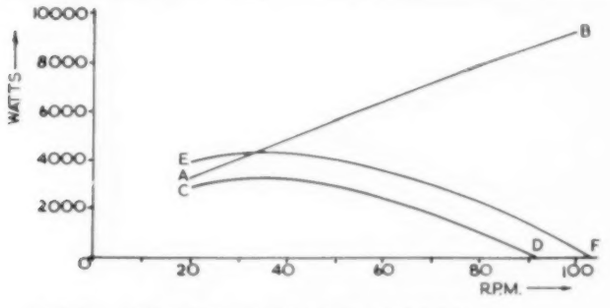



FIG. 3. ENERGY BALANCE DIAGRAM.

The value of $Z_s$, $Z_w$ and $Z_h$ can all be obtained from diagrams of the same type as Figure 3. Based on this procedure, the diagrams in Figure 4 show the efficiency r.p.m. relationships for all four screws for a range of material temperatures. Figure 5 shows how the efficiency of screw 1 varies with changing die aperture and this type of diagram is typical of the other three screws.

A set of curves showing the relationship between output, pressure and r.p.m. for four screws and five dies is shown in the four diagrams of Figure 6.

## Analysis

### 1. Screw Speed Range

Generally speaking, a graph showing the output of an extruder plotted against the r.p.m. of the screw results in an almost straight line relationship at least up to 100 r.p.m. Assuming, therefore, that it is justifiable to extrapolate such a graph, the output might reasonably be expected to double if the screw speed were doubled. On this basis, therefore, one might be justified in assuming that a 2½" extruder running at 200 to 300 r.p.m., producing at the rate of 200 to 300 pounds per hour, even with a larger electric motor, might be a more economical proposition than a 4½" conventional machine running at 80 r.p.m. Unfortunately the increased output which might be expected from a smaller machine running at higher r.p.m.s appears to necessitate a very high energy input. Generally speaking, the material temperature increases as the screw speed increases and the actual power r.p.m. curve traced out as the r.p.m. increases is shown as thick line in Figure 6. The thin lines are the parabolae associated with particular material temperatures. From this it may be seen that the power requirements do not increase linearly with screw speed, as was the case with output. This situation is perfectly satisfactory if the material temperature is maintained below its oxidation limit in the case of polyethylene, or degradation limit in the case of P.V.C. If it became necessary to remain on or within, say, $T_3$ line, in Figure 7, to avoid undesirable temperature effects, then of course the energy requirements would increase with the square of the r.p.m. This, in turn, would necessitate removing the extra energy input by barrel cooling.

Figure 8 shows a power r.p.m. diagram for a normal extrusion temperature of 140°C. and for a temperature of 200°C. The power requirements for the 4/1 C.R. screw and for the 2/1 C.R. 3" pitch screw for screw speeds up to 200 r.p.m. can be read from this graph. It appears from this diagram that about 60 h.p. would be required to turn the 4/1 C.R. screw and about 48 h.p. to turn the 2/1 C.R. screw if the material temperature were confined to 140°C. Extrapolating the output r.p.m. charts an output of 190 pounds an hour would be obtained for the 4/1 C.R. screw at 200 r.p.m. and about 220 pounds an hour for the 2/1 C.R. screw. The outputs are, therefore, almost double, but the power requirements are prohibitive and in fact are greater than the normal supply to the screw of a 4½" machine which would produce at least 350 pounds of material an hour with 50 h.p. If the heaters were adjusted to obtain a material temperature of 200°C., Figure 8 shows that the screw power requirements fall to about 30 h.p. for the 4/1 screw and 15 h.p. for the 2/1 screw. Calculations, however, show that a prohibitive amount of energy would have to be supplied by the heater bands in order to obtain such conditions. The energy contribution required from conducted heat would be difficult even with a longer barrel, since a very steep temperature gradient through the barrel wall and through the ma-

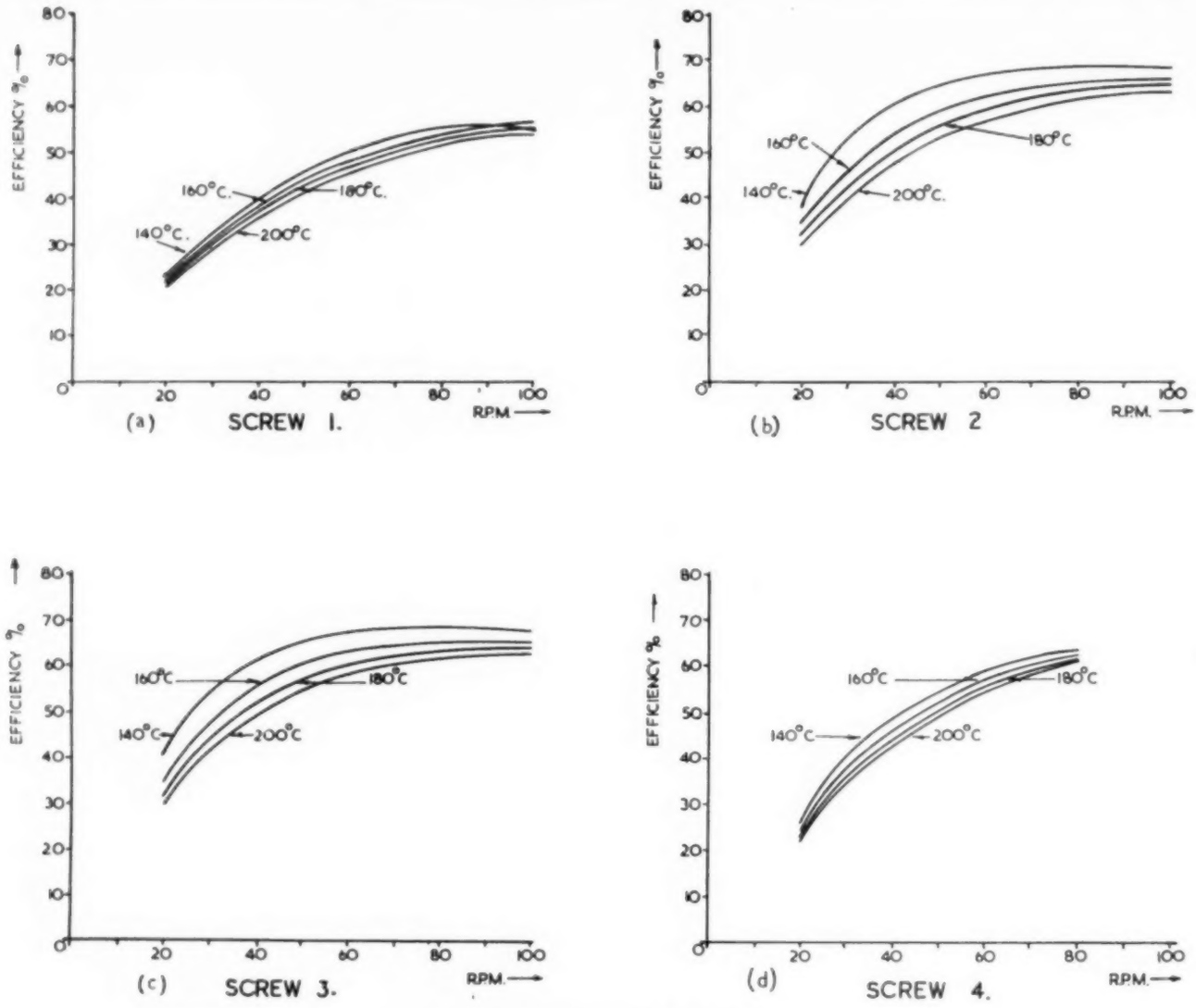



FIG. 4. COMPARATIVE EFFICIENCIES.

terial in the screw flight would be required, such a gradient would almost certainly cause excessive heating in the boundary layer. In addition to these energy difficulties, associated with high speed extrusion, it was also found that on the two-start screw No. 4, the output did not increase linearly with r.p.m. at screw speeds in excess of 70 r.p.m. This is shown in Figure 9 where a fall-away in both output and power can be seen at r.p.m. values higher than 70. This falling-away of output and power requirements was not noticed on any of the three single-start screws when working on Polythene up to 100 r.p.m., but it is reasonable to assume that the phenomenon may occur with these screws at some r.p.m. greater than 100. This difficulty with screws of conventional design would, of course, have to be overcome in order to extrude satisfactorily in the greater than 100 r.p.m. range. In addition to this problem, is the undesirable local overheating produced during high speed work caused by the tremendous shear rate in material in the small clearances above the flights. It is, of course, possible to increase the small clearances, but this would immediately lead to higher rates of leak flow, not only because of the greater clearances and higher temperatures, but also because of the tremendous back pressures developed by these higher speeds. It is not beyond the realm of possibility that a screw could be designed to overcome both the slip problem and the overheating problem, but the final answer to the question of higher screw speeds depends on what is meant by high speeds. It is conceivable that for a 2-3" machine, screw speeds up to 200 r.p.m. may be possible, but it appears to the writer that speeds in excess of this

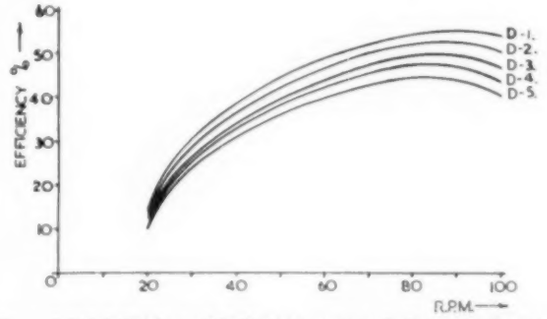



FIG 5. EFFICIENCY VARIATION WITH DIE APERTURE.

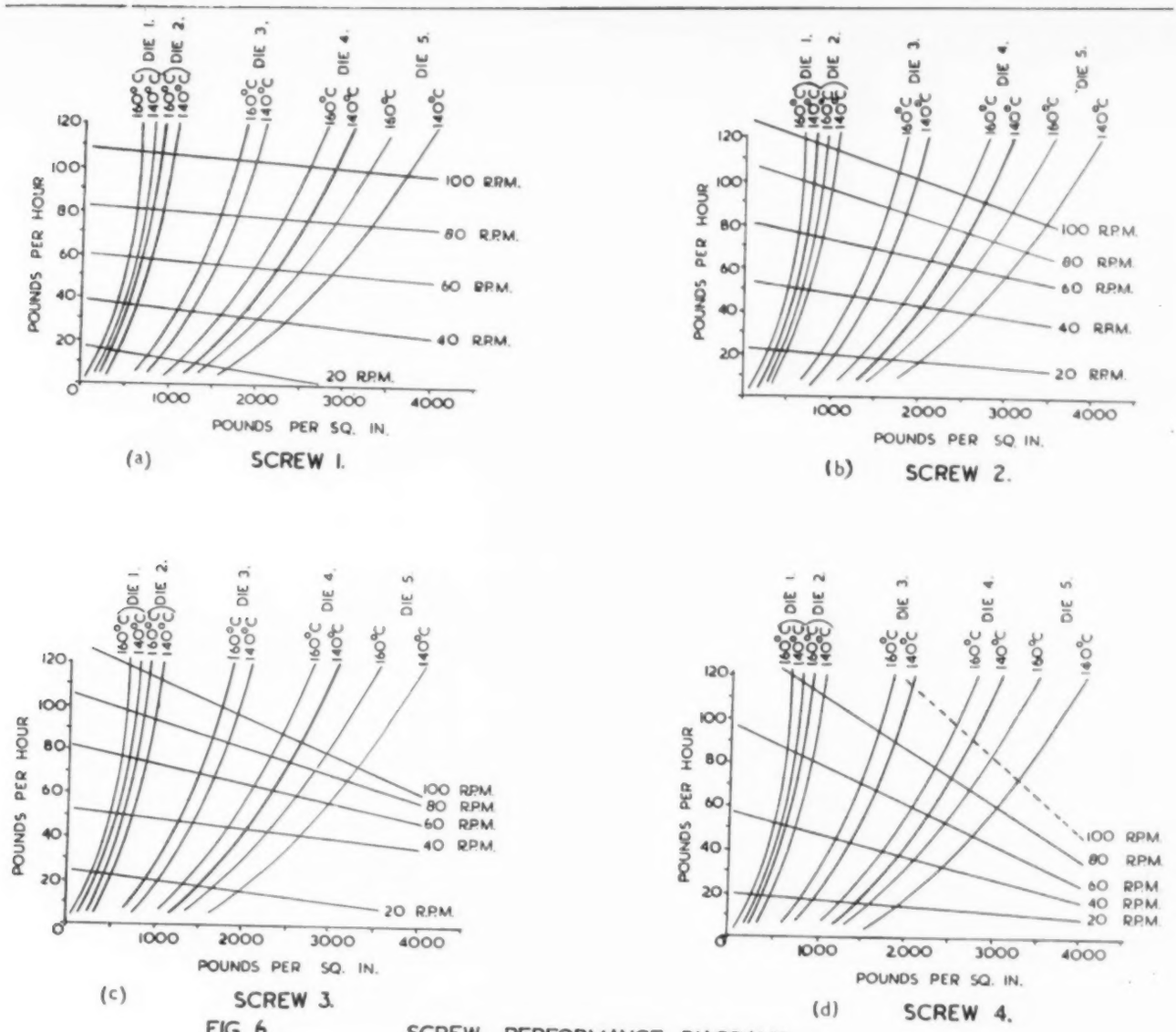



FIG. 6. SCREW PERFORMANCE DIAGRAMS.

are rather out of the question, not only because of the excessive energy requirements and the uncertainty of material behaviour in the screw flights, but also because of the tremendous difficulties associated with cooling and controlling the material delivered at these high speeds. It may be possible that throughout the whole range of extruder sizes, an increase in maximum screw speed up to 2/1 may be possible. The present available evidence does not indicate that speeds in excess of this could reasonably be obtained.

**2. Adiabatic Extrusion**

The experimental results outlined earlier show that for Polythene, adiabatic conditions are easily obtainable on a correctly designed machine. Other work carried out on PECO machines has shown that cellulose acetate may be also extruded in this way and there seeems to be little doubt that with a correctly designed screw most of the common thermoplastic materials, including P.V.C.s, could be extruded adiabatically. Readings obtained from the machine indicate that the extruder obtains a maximum efficiency when the extruder becomes adiabatic, and the connection betweeen the adiabatic point and the maximum efficiency is shown in Figure 10. This can, of course, be appreciated without resorting to a complicated experiment for confirmation. The screw of the extruder supplies energy directly to the material and thereby raises its temperature. The temperature gradient which exists under these circumstances between the material and the external wall of the barrel is in the reverse direction to the gradient required when supplying heat by conduction. This means that far less heat is thrown away in radiation in adiabatic operation. The fact that the shear method of heat input actually produces energy where it is required and avoids the considerable temperature gradients through the plastics material, which the conducted heat method necessitates, are sufficiently good grounds for recommending adiabatic operation.

**3. Screw Characteristics and Their Effect on Output**

**(a) Design of Screw**

In Figure 6 the delivery of all four screws for a variety of dies, material temperatures and screw speeds can be compared.

Confining attention to die D.1 and the material egress temperature of 140°C., it may be seen that in the

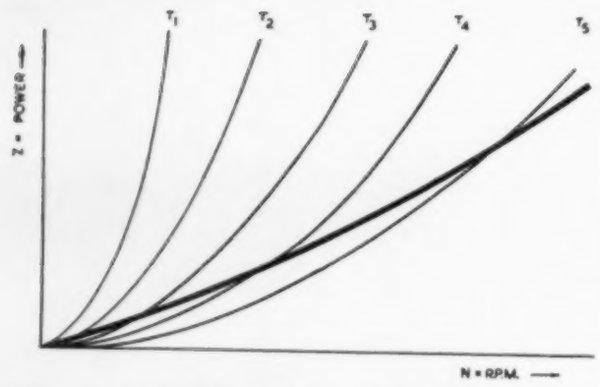



FIG. 7. ACTUAL POWER - R.P.M. RELATIONSHIP.

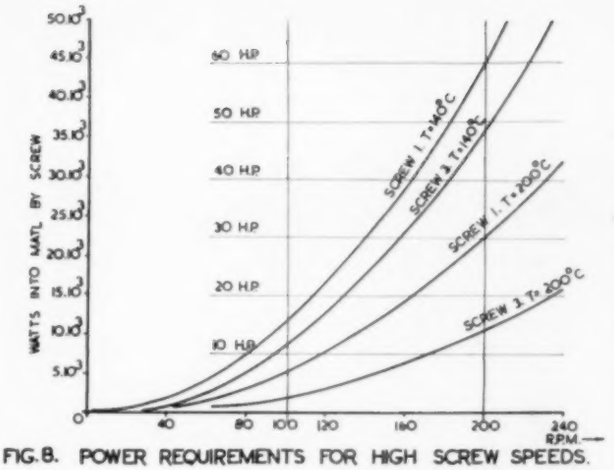



FIG. 8. POWER REQUIREMENTS FOR HIGH SCREW SPEEDS.

lower speed range the two-start screw gives a higher output than any of the other screws. As discussed earlier, at speeds in excess of 70 r.p.m., or thereabouts, the output of this screw becomes erratic and its characteristic shown dotted in Figure 6 (d) cannot be plotted with any accuracy from actual results. The 4/1 C.R. screw No. 1, which has a shallow metering section results in a relatively flat characteristic and regardless of the die size the output for a given r.p.m. remains fairly constant. The 2/1 C.R. screws in Figure 6 (b) (c) and (d) have steeper characteristics due, of course, to the increased depth of the metering section. The effect of changing the pitch of the 2/1 C.R. screw from 2.6" to 3" is shown in the slightly steeper characteristic of (c). From these diagrams it can be seen that screw 1 would be recommended for work on small sections in which the die resistance was fairly high, whereas screws 2 and 3 would be recommended for a fairly large section extrusion. No particular advantage is gained by using the 2-start screw and the uncertainty of output in the upper r.p.m. range of diagram (d) of Figure 6 indicates that this screw is very limited in its working range. A further criticism of this screw is that the extrudate does not appear to be very homogeneous in consistency. This is probably due to the unfavourable length depth ratio of the screw flight. The four diagrams of Figure 6 also indicate the sensitivity of each of the four screws to slight changes in material temperature. This effect is shown to greater advantage in Figure 11, in which the intersection of a screw characteristic and a die characteristic at two different material temperatures is shown for two different screws. From this it may be seen that the output from a 4/1 screw shown in diagram (a) for a material temperature variation of 20°C. is merely 1 pound per hour, whereas for a similar temperature variation on the 2/1 screw as shown in diagram (b), the output varies 3 pounds per hour, thus it may be seen that the output of a screw with a flat characteristic is less sensitive to variation in the material temperature than is the output of a screw with a steep characteristic. These conclusions on screw design refer to Polythene only, but similar processes obviously take place for all thermoplastic materials and the tendencies indicated above would obviously be reproduced to some degree or another with all materials.

**(b) Screw Length-Diameter Ratio**

The length diameter ratios of the majority of extruders at present in Europe vary between 12 and 16 to 1. In the case of materials such as Polythene, cellulose acetate, where there is relatively little danger of material degradation, there does not appear to be any necessity to go beyond 16/1. With these materials the maximum allowable temperature has fairly wide limits and as shown in the experiments, adiabatic operation can be reached

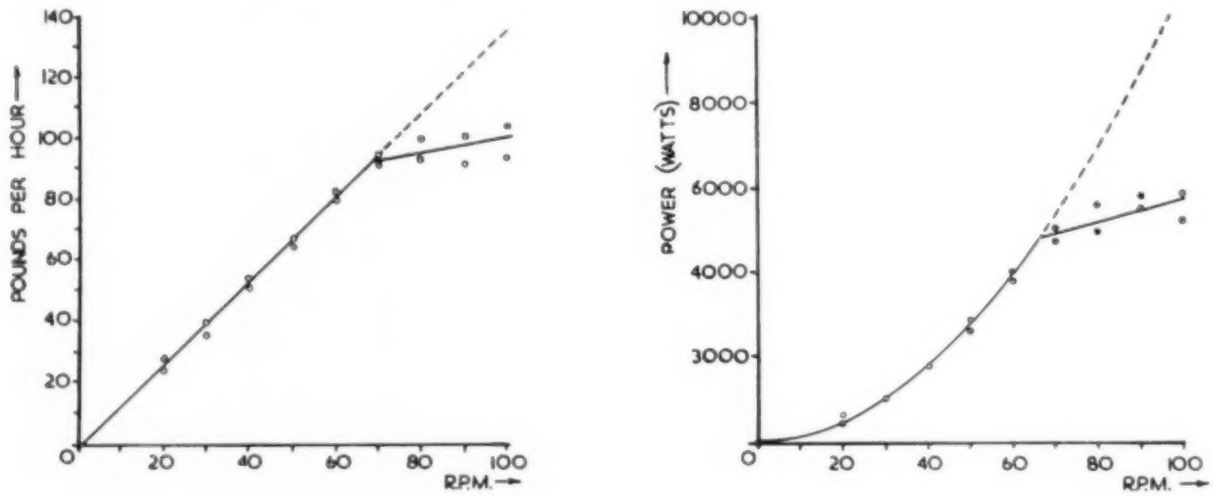



FIG. 9. OUTPUT & POWER PLOTS FOR SCREW 4

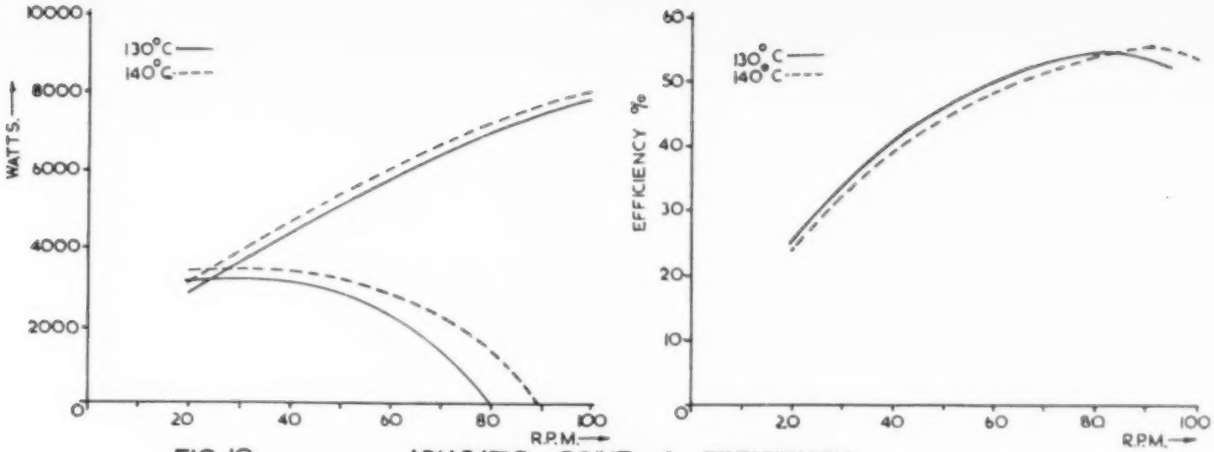



FIG. 10. ADIABATIC POINT & EFFICIENCY.

with the right screw design. Lengthening the screw would be of no assistance, it would only introduce unnecessary mechanical complications.

In the case of unplasticized P.V.C., however, because of the danger of degrading near the melting temperatures, there seems to be some advantage in reducing the heat imput by mechanical work. Local overheating between the barrel and the screw becomes very difficult to control and cooling becomes extremely critical. Thus it appears that with unplasticized P.V.C., reduced compression ratios and longer barrel lengths would be advantageous. It is important, however, to realize that increased lengths of screw and barrel would bring certain mechanical limitations as far as torque requirements are concerned. Therefore, should the length be increased, the torque requirements would have to be reduced by increasing the depth of the metering section or reducing the compression ratio.

A further advantage would be that a longer granular plug is maintained at the feed end of the screw which would give more forward thrust to the material.

**4. Scale-up Considerations.**

Scale up rules indicate that the horsepower required to turn an extruder screw should increase with the cube of the screw diameter if the average viscosity of the material is maintained constant. However, in practice it is found that if the scale rules are followed exactly and the power input to any size of machine is maintained proportional to the diameter cubed, then lower barrel temperatures are required as the machine size increases. This is due to the fact that the ratio between the barrel surface and the volume of material in the flights decreases with increasing diameter and less surface is available to introduce or dissipate heat.

**Adiabatic Operation.**

The lines $N_1 \ldots N_6$ in Figure 12 are cubics showing the theoretical relationship between horsepower and screw diameter whilst the dotted lines show approximately how the actual scale up line goes.

The power requirement from the screw is greater than predicted at first, since the heat input is limited by the available transfer surface. After crossing the cubic lines at the adiabatic condition, the power input is then less than predicted due to the higher material temperature resulting from lower radiation losses. Reverting to Figure 10, the adiabatic point is reached at a lower r.p.m., since the energy input by the screw has a smaller radiation loss for which to compensate, as the screw diameter increases. This change of adiabatic point with r.p.m. can also be seen in Figure 12 and shows that the larger the machine the lower the speed at which it becomes possible to operate adiabatically.

## Efficiency

In Figure 10 it was seen that there is a definite relationship between the point at which an extruder reaches its maximum efficiency and the point at which adiabatic operation becomes possible at a lower r.p.m., it follows that a large machine reaches its maximum efficiency at a lower r.p.m.

(Please turn to Page 56)

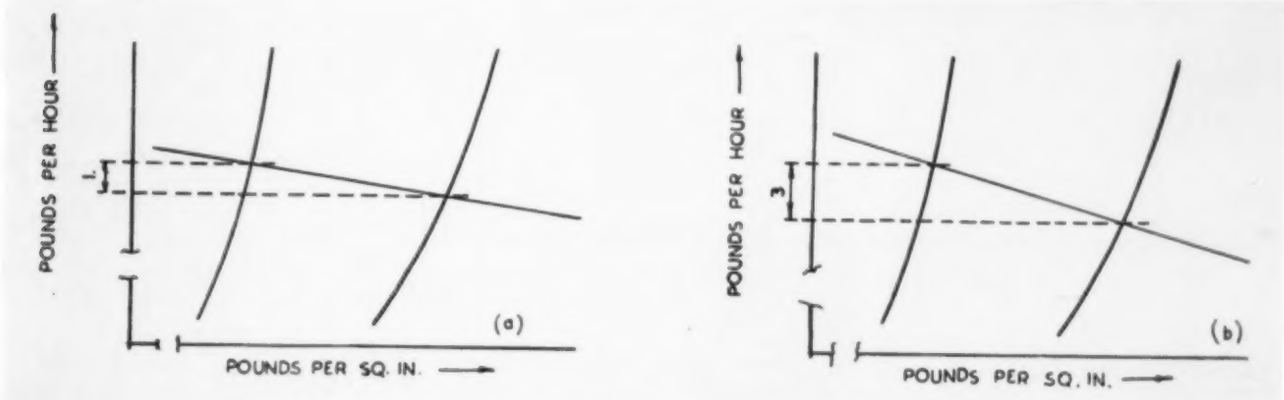



FIG. 11. OUTPUT VARIATION WITH MATERIAL TEMPERATURE.

# 15 Years of Plastics Progress

## *Preliminary Program of SPE's 13th Technical Conference*

The St. Louis Section Conference Committee for the 13th Annual National Technical Conference of the Society of Plastics Engineers, Inc. has completed a major share of the work on the Conference program, Otto Wulfert, General Chairman, has announced.

The event will be held January 16, 17, 18, 1957, at the Sheraton-Jefferson Hotel in downtown St. Louis and has as its theme: "Fifteen Years of Plastics Progress."

The Conference officially begins on Wednesday morning, January 16, at 9:30 a.m. with technical sessions scheduled for mornings and afternoons Wednesday and Thursday and morning sessions on Friday. There will be three separate sessions in each session period, each in a field covering a particular area of interest. Four papers covering the latest technical data in the particular interest field will be developed at each of these sessions. All morning sessions will begin at 9:30 a.m., afternoon sessions at 2:00 p.m.

*Wednesday, January 16, 1957*

Morning Sessions

9:30 a.m. to 12:00 noon

Session I — Gold Room

### ATOMIC

Moderator—DAVID BALLANTINE, *Brookhaven Laboratories*

Some Vital Roles of Plastics in High Energy Nuclear Research — J. O. Turner, *University of California*

Application of a Flexible Plastic for Contamination Control — H. A. Moulthrop, *General Electric Co.*

The Permeability of the Polyethylenes to Gases and Vapors — V. L. Stannett, *State University of New York*

The Corrosivities of Plastics and Rubbers — H. A. Perry, Jr., A. M. Chreitzberg, I. Silver, H. E. Matthews, Jr., *U. S. Naval Ordnance*

Session II — Ivory Room

9:30 a.m. to 12:00 noon

### DESIGN

Moderator—DR. R. B. AKIN, *E. I. duPont deNemours & Co.*

Practical Methods for Controlling the Effect of Moisture on Molded Nylon — H. B. Happoldt, A. J. Cheney, E. M. Lacey, *E. I. duPont deNemours & Co.*

Plastics—An Answer for Industrial Design — R. Hughes, *Emerson Electric Mfg. Co.*

From Appearance Design to Prototype Model — Edward Ferrari, *General Electric Co.*

Can Preformance Tests be Developed for Finished Molded Articles? — R. A. McCarthy, *Monsanto Chemical Co.*

Session III — Crystal Room

9:30 a.m. to 12:00 noon

### TOOLING AND MACHINERY

Moderator—ISLYN THOMAS, *Newark Die*

Continuous Winding Machinery for Plastic Film and Sheeting — John E. Nordgren, *The Black-Clawson Co., Inc.*

The Importance of Mold Rigidity in Injection Molding — R. N. Farris, *The Dow Chemical Co.*

Materials, Tooling and Machines for Injection Molded Packaging — B. Nathanson, *Monsanto Chemical Co.*

The Engineering of Molds Utilizing Electroformed Cavities — W. J. B. Stokes, III, *Electromold Corp.*

*Wednesday, January 16, 1957*

Afternoon Sessions

2:00 to 4:30 p.m.

Session I — Ivory Room

### EXTRUSION I

Moderator—CLEM YOUNG, *Crescent Plastics*

Factors Affecting Quality in Polyethylene Extrusions — B. H. Maddock, *Bakelite Co.*

Flow of Polyethylene Through Circular Dies — D. I. Marshall, *Bakelite Co.*

Multiple Orfice Extrusion — E. C. Bernhardt, *E. I. duPont deNemours & Co.*

Effect of Blow-up Ratio on Blown Polyethylene Film Properties — *Spencer Chemical Co.*

Session II — Gold Room

2:00 to 4:30 p.m.

### INJECTION MOLDING I

Moderator-DR. LOUIS F. RAHM, *Princeton University*

The Molding of Linear Type Polyethylene — James W. Flynn, *Celanese Corp. of America*

Injection Speed Considerations — L. E. Tallman, O. G. Maxson, *Dow Chemical Co.*

Uniformity Considerations for Plastic Stock Temperature in Injection Molding — *A. L. Bird, Joe Eveland, Dow Chemical Co., Plastics Tech. Serv.*

Molding of "Teflon" Tetrafluorethylene Resin — F. M. Chapman, L. T. Bunn, *E. I. duPont deNemours*

Session III — Crystal Room

2:00 to 4:30 p.m.

### FOAMS

Moderator—ARNOLD VARNER, *General Electric Co.*

Polystyrene Foam — A Low Density Molding Material — D. L. Graham, *Dow Chemical Co., Plastics Tech. Serv.*

Polystyrene—A Versatile Foaming Material — R. N. Kennedy, G. R. Franson, *Dow Chemical Co., Plastics Tech. Serv.*

Plastics Sandwich Construction — G. D. Miller, H. J. Waite, *Dow Chemical Co., Plastics Tech. Serv.*

Use and Application of Isocyanate Foams — Benjamin S. Collins, *Nopco Chemical Co.*

*Thursday, January 17, 1957*

Session I — Gold Room

INJECTION MOLDING II

Moderator—GORDON THAYER, *Dow Chemical Co.*

Hydraulic System and Its Relation to Polymer Flow Through an Injection Molding Machine — O. M. Hahn, J. B. Broussard, *E. I. duPont deNemours & Co.*

Pressure Measurement in Injection Molding—Use of Ejector Pins — P. D. Kohl, *E. I. duPont deNemours & Co.*

A Discussion of Bulk Compressability of Polymers and Effect of this Compressability on the Flow Properties — S. Matsuoka, *Princeton University*

New Gating for Acrylics — J. F. Moore, *Rohm and Haas Co.*

Session II — Ivory Room

9:00 a.m. to 12:00 noon

EXTRUSION II

Moderator—GEORGE PRALL, *Western Textile Products*

Shape Extrusion Studies of "Zytel" Nylon Resin — K. G. Toll, *E. I. duPont deNemours & Co.*

Rigid Thermoplastics Piping (Cycolac) — R. K. Multer, *Marbon Chemical Co.*

Applications of Extrusion Theory — R. E. Colwell, *Monsanto Chemical Co.*

Nylon 6 Extrusion — *Spencer Chemical Co.*

Session III — Crystal Room

2:00 to 4:30 p.m.

APPLICATIONS

Moderator—DR. ALBERT LIGHTBODY, *U. S. Naval Ordnance*

Vinyl-Clad Steel — Glenn E. Wintermute, *Arvin Industries, Inc.*

A Method of Testing Quality of Phonograph Records — N. J. Gifford, P. C. Woodland, *Dow Chemical Co.*

New Fabrication Techniques for Flush Circuitry — P. E. Ritt, E. L. Ditz, *Melpar, Inc.*

Stability of Nylon Parts in Business Machines — Byron W. Nelson, *National Cash Register Co.*

*Thursday, January 17, 1957*

Afternoon Sessions

2:00 to 4:30 p.m.

Session I — Gold Room

REINFORCED PLASTICS I

Moderator—R. J. SAVAGE, *Celanese Corp.*

Commercial Applications of "B" Stage Preimpregnated Material vs. Wet Layup Systems — S. G. Salzinger, *Coast Mfg. Co.*

The Problems of Fittings to Match the Performance of High Pressure Reinforced Plastic Pipe — H. D. Boggs *The Fibercast Corp.*

Plastic Compressor Rotor Blades for Turbo Jet Engines — *General Electric Co.*

Molding Thick Glass—Reinforced Polyester Laminates — F. Claudi-Magnussen, *Hooker Electrochemical Co.*

Session II — Crystal Room

2:00 to 4:30 p.m.

INSTRUMENTATION

Moderator—DON C. WALLEY, *K-S-H Plastics*

Watt Density and Thermocouple Location Studies on the Injection Molding Heater — R. B. McKee, R. B. Dahl, *Dow Chemical Co.*

Pressure Control for Injection Molding Machines — C. E. Beyer, *Dow Chemical Co.*

Platen Press Temperature Control — J. C. Stansel, *General Electric Co.*

Advantages of Dual Thermocouples in Injection Cylinders and Extruder Barrels — Richard K. West, *West Instrument Corp.*

Session III — Ivory Room

2:00 to 4:30 p.m.

COMPRESSION MOLDING

Moderator—EDWARD F. BORRO, SR., *Hooker Electrochemical Co.*

The Use of Alkyd Molding Compounds In Electrical and Electronic Applications — James J. Moylan, *Barrett Division, Allied Chemical & Dye Corp.*

Advanced Tooling Techniques for Molding High Impact Thermosetting Materials — Edwin Keusch *The Fiberlite Corp.*

Synthetic Fiber Reinforcement of Thermosetting Resin Laminates — John G. Green, Jr., *E. I. duPont deNemours & Co.*

A Discussion on a Fully Automatic Transfer Molding Machine — John J. Hull, *Hull-Standard Corp.*

Session IV — Meeting Room 1

2:00 to 4:30 p.m.

RESEARCH SYMPOSIUM

Moderator—ELI HADDAD, *Monsanto Chemical Co.*

*Friday, January 18, 1957*

Morning Sessions

9:00 a.m. to 12:00 noon

Session I — Ivory Room

POLYETHYLENE

Moderator—JOHN HOWARD, *Bell Laboratories*

Dimensional Stability of Linear Polyethylene — R. W. Miller, *W. C. Sager, Dow Chemical Co.*

Linear Polyethylene as a Melt Spun Fiber — T. C. Broadwell, A. T. Widiger, G. H. Yousse, *Dow Chemical Co.*

Property—Structure Relationships in Polyethylene — H. M. Spurlin, W. O. Bracken, *Hercules Powder Co.*

A Method of Evaluation of Polyethylene Molding Compounds — *Spencer Chemical Co.*

Session II — Gold Room

9:00 a.m to 12:00 noon

REINFORCED PLASTICS II

Moderator—RALPH SONNEBORN, *Owens-Corning*

Development of High Temperature Resin Glass Systems — *S. G. Salzinger, Coast Mfg. Co.*

"Lucite" Acrylic Resin Syrup for Reinforced Structures — M. S. Ziegler, A. Stockfleth, *E. I. duPont deNemours & Co.*

Extreme Strength Reinforced Plastics Film Systems — John Bjorksten, Risto P. Lappalo, *Bjorksten Research Laboratories*

Estimating in Reinforced Plastics — Frank W. Sheffler, *Lunn Laminates, Inc.*

Session III — Crystal Room

9:00 a.m. to 12:00 noon

EPOXIES

Moderator—JERRY FORMO, *Minneapolis Honeywell*

Reactive Diluents in Epoxy Resin Systems — Elliott N. Dorman, *Ciba Co., Inc.*

Epoxy Encapsulation of Transistor Flip-Flops — P. E. Ritt, R. F. Marshall, *Melpar, Inc.*

Polysulfide Liquid Polymer Epoxy Resin Compounds in Plastic Tooling Applications — Alan J. Breslau, Earl H. Sorg, *Thiokol Chemical Corp.*

Manufacturing Considerations Associated with Encapsulating, Embedment and Potting Processes — C. A. Harper, *Westinghouse Electric Corp.*

Session IV — Meeting Room 1

9:00 a.m. to 12:00 noon

EDUCATIONAL SYMPOSIUM

Moderator—R. C. BARTLETT, *Natvar Co.*

# VISCOSITY DATA

# For Extruder F

Robert D. Sackett
*Monsanto Chemical Company*

EXTRUSION as a means of compounding and fabricating plastic materials is becoming of increasing importance. With the anticipated growth in the output of vinyl and polyethylene over the next five years, we will undoubtedly see a correspondingly large growth in extrusion, inasmuch as it is the major means of fabricating these two thermoplastic materials.

Low capital investment, high flexibility and virtually continuous operation all have made extrusion an attractive manufacturing process. Its rapid growth has been a natural consequence.

In many ways, however, the extrusion field has grown faster than it has matured. As a result it is still more art than science.

Independently, machine manufacturers, raw material suppliers and custom extruders have developed a wealth of knowledge on various extrusion problems. Although each has been successful in his own way, the individual approaches have been unintegrated. Any discussion of "preferred methods" therefore leads only to controversy.

Because of the increasing importance of extrusion, as a means of both compounding and fabricating plastics economically, considerable effort has been expended in developing a more scientific approach to this problem. Of noteworthy interest among recent developments in the field of extrusion has been the development of a number of useful extruder flow equations (1). These equations have aided considerably in helping the extrusion engineer arrive at a fundamental understanding of what occurs in an extruder under ideal conditions. One might say that extrusion now is approaching the area of a "scientific art." The theories developed have not supplanted the many years of practical extrusion know-how that has been developed, but serve as a tool in helping us make predictions and study trends which can be tempered by practical experience. Aside from the value of the extruder flow equations in helping us understand that which we observe, they also can be of considerable aid in making extruder design calculations.

An important parameter about which little information exists presently is the "apparent extrusion viscosity" of the plastic melt. In this paper a method is described for determining the apparent extrusion viscosity and the temperature coefficient of viscosity. Data is also given to show the approximate effect of shear rate on the extrusion viscosity of polystyrene.

For those not thoroughly familiar with the work that has been done on the theory of extrusion over the past few years, a moment should be devoted to reviewing some of the fundamental assumptions made, some of the terms used, and the extruder flow equations themselves.

Figure 1 is a schematic drawing of the various sections of an extruder worm. For the sake of conversation the worm normally is divided into four major sections. The **feed section** or solids conveying portion of the screw is normally about two diameters in length with the feed hopper extending over about one diameter of this. Theoretical means (2) have been devised for calculating the exact dimensions of this section. Our experience has indicated that normally this section is over-designed as much as ten times in some cases and its exact dimensions are not critical.

Generally the **compression section** runs from three to six diameters in length and is the transition zone where material is partially in the solid form and partially in a melt form. Compression is obtained either by increasing the root diameter and holding the helix angle constant or by decreasing the helix angle and maintaining the root diameter constant. In some cases a combination of both is used.

The **metering section** (two to five diameters) is referred to arbitrarily as that section where the screw has

**Figure 1 A Typical Worm Constant Pitch-Variable Root Diameter**

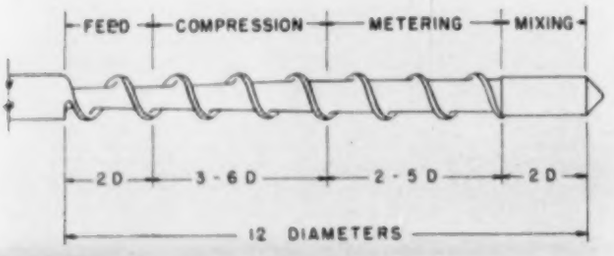
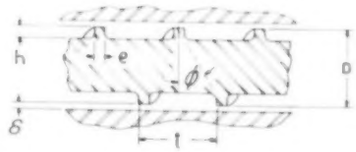



**Figure 2**

NOMENCLATURE




| | |
|---|---|
| $\pi$ = 3.1416 | N = REVOLUTIONS ---------- RPS |
| D = DIAMETER ---------- IN | $\Delta P$ = PRESSURE DIFF ------ PSI |
| t = PITCH = $\pi D \tan \phi$ ------ IN | $\phi$ = HELIX ANGLE |
| h = FLIGHT DEPTH ---------- IN | f = $\delta / h$ |
| $h^*$ = EFFECTIVE DEPTH ------ IN | Q = OUTPUT ---------- $IN^3/SEC$ |
| e = WIDTH OF FLIGHT LAND - IN | $\delta$ = SCREW CLEARANCE -- IN |
| $l_x$ = DISTANCE BETWEEN PRESSURE POINTS --- IN | |
| $\mu$ = VISCOSITY - LBS FORCE - SEC / $IN^2$ | |

# Flow Equations

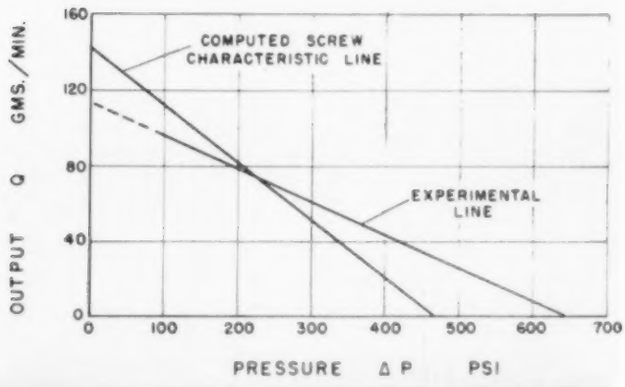
constant geometry or where the plastic is a melt. Under such conditions fundamental laws can be applied. This paper is concerned primarily with this section of the screw, which not only holds the key to most extrusion problems but actually controls the output. Using the extruder flow equations (1) considerable success has been obtained in making theoretical calculations concerning the output and physical dimensions of the metering section.

In some cases it is desirable to add some device, such as a torpedo, to improve the mixing characteristics of the extruder worm. Where such devices are used, they are considered normally as part of the resistance against which the worm must operate, as the forwarding capacity of the mixing section is normally negligible.

Figure 3

EXPERIMENTAL vs COMPUTED CHARACTERISTIC LINE

POLYSTYRENE - 415 °F - 30 RPM




The referenced flow equations (1) used in this work were based on the assumption that the plastics involved behave as Newtonian fluids, although it was realized that non-Newtonian fluids are involved in the case of plastics. The idealized conditions assumed, however, have done much towards explaining what occurs in the metering section. The flow equations do not take into consideration quality aspects of extrusion and consequently, in many instances, it is necessary to temper calculated results on the basis of prior experience.

Two separate sets of equations (1) (3) have been developed based on the following theories. In the first case isothermal conditions are considered. It is assumed that the temperature of the plastic melt is constant throughout the length of its flow path. No heat is transferred to or out of the material, or generated by viscous shearing. In other words material enters and leaves the metering section at the same temperature.

The second theory is considerably more complex and involves the adiabatic case. Here we assume that the temperature increases as the material flows through the metering section, but that all of the heat is derived by mechanical means. No heat is transferred into or out of the plastic and the heat applied to the barrel is merely to compensate for the radiation losses to the atmosphere. In reality neither of these cases exists specifically, but actual conditions do lie somewhere between the two. This paper deals with the simpler case, isothermal conditions, as we have found that this theory has the greater practical value and will explain most of our problems.

The essence of the referenced theoretical work has been the development of flow equations for determining output, flight depth, length of metering section, pressure developing capacities and the helix angle for a given screw when operating under ideal conditions. Three major flows occur in a melt extruder:

**Drag Flow** is the forward flow resulting from the relative motion between the barrel and the cylinder wall.

**Pressure Flow** is a reverse flow along the screw channel caused by the resistance of the screen, breaker plate and die.

**Leakage Flow** is the flow of material over the top of the flights and is proportional to the clearance between the flights and the barrel.

Figure 2 is an explanation of the terms used in the extruder flow equations. The term $h^*$ (4), the effective flight depth, has been used in this work in place of the measured "h" as it has been found that better correlation between theory and practice could be obtained by this means. Figure 3 is a familiar plot to the extrusion engineer. It is a plot of the output of the extruder ver-

Figure 4

ISOTHERMAL FLOW EQUATIONS

$$Q_{TOTAL} = Q_{DRAG} - Q_{PRESSURE} - Q_{LEAKAGE}$$

$$Q_T = a_o h^* N - \frac{\beta_o h^{*3} \Delta P}{\mu} - \frac{\gamma_o h^{*3} \Delta P}{\mu}$$

$$a_o = \frac{\pi D (t-e) \cos^2 \phi}{2} \quad \text{DRAG FLOW CONSTANT}$$

$$\beta_o = \frac{(t-e) \sin \phi \cos \phi}{12 \; l_x} \quad \text{PRESSURE FLOW CONSTANT}$$

$$\gamma_o = \frac{\pi^2 D^2 f^3 \tan \phi}{10 \; e \; l_x} \quad \text{LEAKAGE FLOW CONSTANT}$$

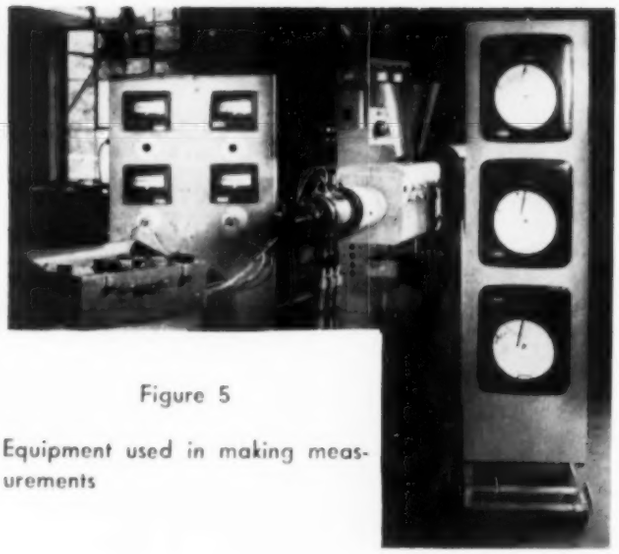


Figure 5

Equipment used in making measurements

sus the pressure at the die, or in this case, the pressure drop across the metering section. The plot is known as the screw characteristic line. One of the lines is marked "calculated" and the other is the "experimental" line which is an actual performance plot run on the given screw. The reason for the poor fit may be assumed to result from thermal effects that were neglected in the original flow equations. It also can be accounted for in part by the non-Newtonian character of the plastic material. By introducing a ficticious value "h*" for the flight depth, this apparent deficiency is corrected. The effective flight depth is calculated from the intercept of the extra-polatoled data and the output ordinate in the plot. This is an empirical correction which may not apply to all types of flow variations.

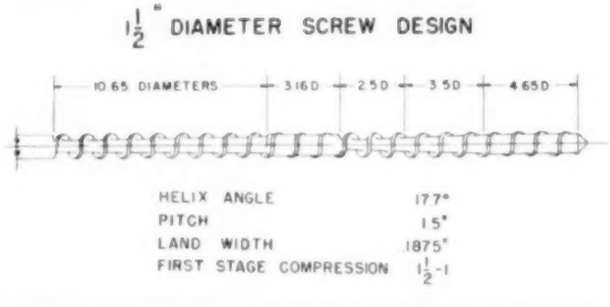
The total output (1) of the extruder is equal to the drag flow—minus the pressure and leakage flows as shown in the simplified equations in Figure 4. $\alpha_n$, $\beta_n$, $\lambda_n$ refer to the drag, pressure, and leakage flow constants respectively and can be expressed by the geometry of the screw. All of the other terms shown in the equation are readily obtainable with the exception of $\Delta P$, $l_x$ and $\mu$ (the viscosity). By properly installing pressure gauges along the barrel at known distances apart, both $l_x$ and $\Delta$ P can be obtained. In actual practice helpful information has been obtained by using pressure at the die for $\Delta$ P and assuming that $l_x$ is the length of the metering section. The remaining unknown term is viscosity and this must be known before full use of the equations can be made.

One not familiar with the many complexities of the science of rheology finds it difficult to understand why, in this modern age, there should be any great problem in determining the viscosity of a plastic melt. This is, however, an extremely complex subject when non-Newtonian materials such as plastics are involved. Of primary concern to us in determining apparent extrusion viscosity is the fact that viscosity is shear rate dependent. In other words, viscosity values vary depending upon the rate at which the particular viscometer involved actually shears the plastic being measured. In addition, viscosity data available, run on conventional viscometers such as parallel plate, rotational and Nason rheometer types, generally are reported at rates of shear considerably below those encountered in an extruder. Work done on a modification of a capillary viscometer (5) shows promise of being adaptable for use in determining extrusion viscosity data. Present data reported on such equipment is believed to be at rates of shear not directly comparable to extrusion and a method of correlating this information for use in the flow equations is believed necessary.

In the work described in this paper an actual extruder was set up as a rheometer. Provisions were made for either measuring or determining all of the unknown terms in the extruder flow equations (1) except the extrusion viscosity. What we actually are saying is that the theory is fundamentally correct and then determining what number should be substituted for the extrusion viscosity to give the answer which the theory predicts. Numbers obtained by this procedure are not precise, but are intended as close approximations of the proper value to be used in extruder design calculations. It should be recalled that fundamental assumptions applied in deriving the extruder flow equations were that isothermal conditions existed and that Newtonian fluids were involved. Inasmuch as we know that these conditions do not exist precisely, we use these equations to indicate trends and to give approximations. This being the case, we do not recommend using exact values for viscosity, but suggest picking a range of viscosity values and thus bracketing actual extruder conditions.

A photograph of the equipment used in making these measurements is shown in Figure 5. The extruder is a 1½" diameter machine with a 23 l/D ratio with a devolatilizing section. Shown in the photograph is the pressure recording equipment, auxiliary barrel pyrometers and a potentiometer for measuring stock temperature.

Figure 6

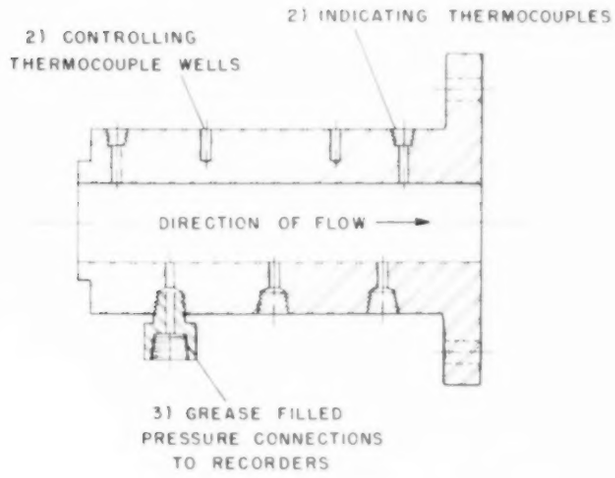



A sketch of the worm is shown in Figure 6. It has a 1½ to 1 compression ratio in the first stage and then passes through a shallower flighted section to give a pressure drop before the devolatilizing section. A deep flight is used in the vent section and the screw is designed so that the flights are full, though in some cases material actually flows from the vent. A vented type extruder was used so that we could be sure that the material was well plasticized and that the metering section was full with a plastic melt. Leading from the vent section is a short compression section and then a metering section 5 diameters long. The flight depth in the metering section is 0.1" and the helix angle is 17.8° giving a pitch of 1½".

Figure 7 is a sketch of the metering section of the barrel, showing the location of the pressure gauges and thermocouples. Three recording type pressure gauges were used equipped with sabre type connections. Silicone vacuum grease was used as the pressure transfer medium. Recording type pressure instruments gave more precise measurements than would have been possible with a standard indicating type gauge because of the pressure

Figure 7

METERING SECTION OF BARREL

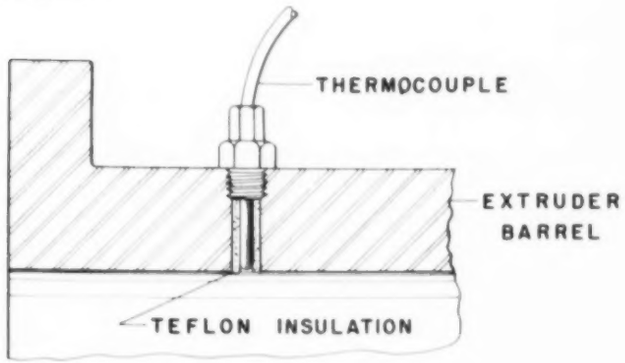

2) INDICATING THERMOCOUPLES
2) CONTROLLING THERMOCOUPLE WELLS
DIRECTION OF FLOW
3) GREASE FILLED PRESSURE CONNECTIONS TO RECORDERS

differential across a given flight and the resulting difficulty in reading the fluctuating pointer. Actual calculations and measurements were taken only on the two forward gauges and the distance between them is the $l_x$ in the flow equations and the pressure difference is the $\Delta P$. The third pressure gauge is used merely to indicate once again that the section prior to the metering section is full.

Two controlling thermocouple wells were located on the top of the barrel regulating the cylinder temperature.

To measure the stock temperature, two thermocouples were mounted flush with the inside of the barrel so that the tip of the thermocouple was constantly wiped clean. A closeup of the thermocouple arrangement is shown in Figure 8. A Teflon insulating sleeve is used around the thermocouple to minimize the effect of the barrel temperature on the reading. A standard potentiometer measured the stock temperature. A temperature increase along the barrel was observed due to frictional heat and the average of the two locations was taken as the temperature of the stock at the point where the pressure was measured. A simple variable restriction die was used in order to change the back pressure to obtain values for the pressure output plot.

Figure 8




TEMPERATURE SET UP

Various thermoplastics were run at three representative temperatures and at three different pressure drops across the metering section. Screw characteristic lines were plotted by plotting the output versus the pressure differential. From this information and the geometry of the screw, it was possible to calculate a value for the viscosity of the plastic at a given temperature.

It can be shown, by manipulating the flow equations, that the output at zero discharge pressure is equal to the drag flow. The expression for the drag flow is $\alpha_o h^* N$, where both $\alpha_o$ and N are known. From this expression, we can calculate the effective flight depth $h^*$ to use in subsequent calculations.

Figure 9 is a sample calculation. By further rearrangement of the equations it can be shown that when the output equals zero and the pressure is at a maximum as read from the previous plot, the flow equation can be rewritten:

$$\mu = (\beta_o + \gamma_o)\, h^{*2}\, \Delta P / l_x$$

Using this equation the viscosity can be determined as all other terms are known. The leakage flow ($\gamma_o$) can be neglected if the extruder is designed with small clearances. This was the case with the extruder used in this work.

Plotting the log of the viscosity versus the temperature, permits us to read from the plot the viscosity at any

Figure 9

SAMPLE CALCULATION

MATERIAL • POLYSTYRENE $\quad \beta_o = 14.9 \times 10^{-3}$

N = 1 RPS $\quad Q = .238$ IN$^3$/SEC

$q_o = 2.8 \quad l_x = 2.09$"

$\gamma = 7.5 \times 10^{-5}$ (NEGLECT)

$$Q = q_o h^* N - \frac{(\beta_o + \gamma_o)\, h^{*3} \Delta P}{\mu}$$

WHEN $\Delta P = 0$,

$Q = q_o h^* N, \quad h^* = .085$" ($h_{\text{ACTUAL}} = 1$")

WHEN $Q = 0$, $\Delta P_{\text{MAX.}} = 490$ PSI AND

$$\mu = \frac{(\beta_o + \gamma_o)\, h^{*2} \Delta P}{q_o N}$$

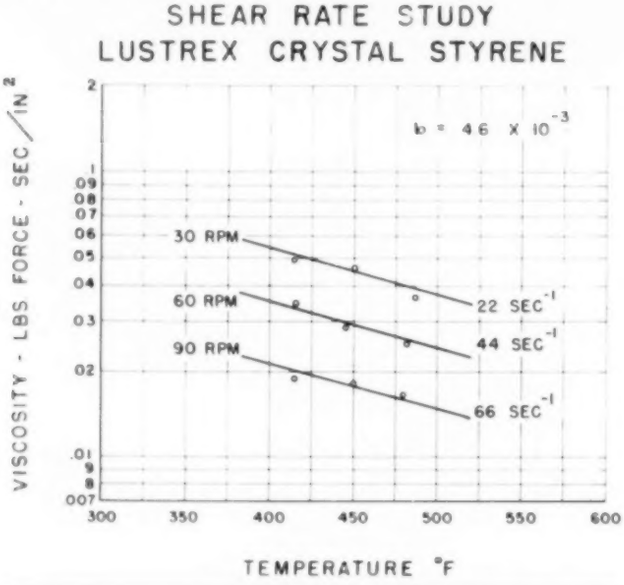
$\mu = .0188$ LBS. FORCE · SEC / IN$^2$

given temperature. Figure 10 shows the values obtained for the several thermoplastics evaluated.

The data shown in this plot differ somewhat from information that has been previously published, (6) and this difference can be accounted for in part by the fact that the rates of shear at which the viscosity was determined are not directly comparable with those used in our work.

The term "$\mu$", apparent extrusion viscosity as determined by the method described in this paper not only includes the viscosity factor of the extruder flow equations, but also includes any descrepancies in the derivation of the equations and any effects due to the variability of the equipment and material. The magnitude and importance of these variables has not been determined but it is not felt that they are of major importance. If such

Figure 10




variables are significant, then viscosities determined by other methods would have the same shortcomings in meeting the requirements of the equation.

An equation of the line in Figure 10 is:

$$\mu = ae^{-bt}$$

where "b" is the temperature coefficient of viscosity; "a" is the correlation factor and is actually the intercept of the viscosity line with the viscosity axis at zero temperature.

This equation can be rearranged in the form of:

$$b = (\log_e \mu_0/\mu_2) / (t_2 - t_0)$$

Using this equation it is possible to calculate the temperature coefficient of viscosity (the slope of the line) and values determined for the several thermoplastics evaluated are given below:

| | |
|---|---|
| Polystyrene | $4.6 \times 10^{-3}$ |
| Styrene Acrylonitirile | $3.6 \times 10^{-3}$ |
| Vinyl Chloride | $1.5 \times 10^{-2}$ |
| Polyethylene | $3.2 \times 10^{-3}$ |
| Cellulose Acetate Butyrate | $1.9 \times 10^{-2}$ |

In conjunction with this study, work was done to determine how great the shear rate dependency of the viscosity actually was and to determine whether the temperature coefficient of viscosity would vary at different shear rates. Figure 11 is a plot of the log of the viscosity versus the temperature for polystyrene run at three different rates of shear or three different rpm values. It is interesting to note that although the specific value for viscosity changed as much as 50 per cent in going from 66 sec $^{-1}$ to 22 sec $^{-1}$ shear rate, the temperature coefficient of viscosity is essentially unchanged. An examination of data taken from the work of Karam, Cleereman, and Williams (5) done on a capillary viscometer, confirms the fact that the temperature coefficient remains constant at different rates of shear.

The specific value of temperature coefficient of viscosity reported in the reference differs by about 20 per cent from that reported in this work but shows essentially no change at different shear rates. An explanation of the difference obtained by the capillary method and the extrusion method possibly could be attributed to a temperature rise occurring in the capillary.

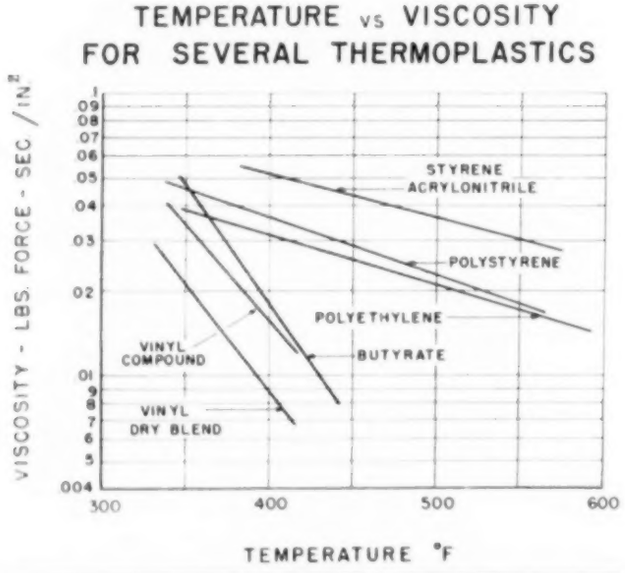
Values of shear rate reported in this paper are nominal values calculated by using the simple equation:

$$\text{Nominal shear rate} = \pi DN/h$$

where D equals the diameter of a circle drawn through the mid point of the flight depth.

The method and values described in this report are regarded as suitable for approximate values of apparent extrusion viscosity for use in the extruder flow equations. However, this procedure is not recommended where it is desirable to make rather fine distinctions between one formulation and another. Because of the variations of extrusion viscosity with the method used and the shear rates involved, it is important that in making extruder design calculation a range of values be used for apparent extrusion viscosity in all cases.

Figure 11




## References


1. Carley, J. F., Strub, R. A., Mallouk, R. S., McKelvey, J. F., Jepson, C. H. Symposium on The Theory of Plastic Extrusion, Industrial Engineering Chemistry, **45**, 969 (1953).

2. Darnell, W. H., Mol, E. A. J., Solids Conveying in Extruders, Society of Plastics Engineers Technical Conference, 1955.

3. Bernhardt, E. C., McKelvey, J. M., Adiabatic Extrusion of Polyethylene, SPE Journal **10**, March, 1954.

4. Colwell, R. E., Unpublished Monsanto Chemical Company Report.

5. Karam, H. J., Cleereman, F. J., Williams, J. F., The Caplastometer: A New Melt Viscometer, Modern Plastics, **32**, 7, March, 1955.

6. Bernhardt, E. C., Calculating Extruder Performance, Modern Plastics, **32**, February, 1955.

*Basic Factors to be Considered in . . .*

# Developing Cost of Molds

John A. Kavanagh
*Vice President, Standard Tool Company*

THE ABOVE title is one that can be interpreted many ways, but let's say that I choose to interpret the title as follows: "Why Do Molds Cost So Much?"

Basically the cost of a mold is entirely dependent upon the intricacy of the article to be produced and the number of cavities of that article to be made at any one time. This is fundamental but for the purposes of this discussion, certainly not important.

The cost of any mold, however, is entirely dependent upon two major factors today: one, the hours of labor consumed to build the mold; and two, the actual cost of building it, reflecting the material used and the construction.

With particular reference to labor, by far the majority of molds must be made in less time than it is economically sound to produce them. First of all, the mold maker makes an estimate of the cost and then quotes a delivery date. Let us say that the delivery quoted in this particular case is for a mold that will take 14 to 16 weeks. The customer, that is the molder, undoubtedly prodded by his customer, states that he can only place the order if he can receive the mold in 10 to 12 weeks. The difference in time must be made up some way and the only way that it can be done is to work more hours in a given day so that excessive overtime is required.

There is a law passed in this country that states after 40 hours of any work week, an employee must be paid on the basis of time and a half and in some instances, double-time work, say on holidays or Sunday or possibly Saturday. Therefore, if a normal week is 40 hours and it becomes necessary to put 60 hours a week per man on the job, there are 20 overtime hours at the rate of time and a half, or double time. The mold maker's customer has then got to pay for 70 or 80 hours cost because of this premium pay, but receives only 60 hours of actual expended labor. To make matters worse, efficiency of working tool makers on a 60-hour basis or more is poor, so not only do you pay for excessive overtime in dollars but also the efficiency of the manpower is substantially lowered.

## Lack of Preparation

As a mold maker, it is very obvious that there is a definite lack of preparation, a definite lack of proper planning on the part of the ultimate manufacturer who has to use the article. It seems that most of the buyers of plastic parts have a chronic disease which never allows them to make a definite decision until so much time is lost that it must be made up by someone else under adverse conditions and at an expense to himself that is far above what it should be.

It was stated by one of the gentlemen on this panel that often times the material estimates are way beyond the actual weight of the finished product; in some cases, way below the weight so that the discrepancy seems almost inexcusable. If this is the case, it can only mean that where the molder estimated in excess of what it actually was, that the product quoted was a much higher price than need be. If it is the reverse, naturally, the quotation is too low and cannot be produced at a profit and must call for a revised price scheduling which in many cases cannot be tolerated. Therefore, preparation in advance by making a model out of the material to be produced would give the proper weights and most of all—as far as the mold maker is concerned give a visual sample to quote on, to design the mold from. It would be possible to check well in advance any features in this article that should be changed in order to lower cost, not only in the mold but in the actual molding. This would also help in making proper mold prices possible.

## Heart of the Operation

Now to cost itself. The mold is the heart of the operation. It produces the product and if the product does not come up to standards, it is generally the fault of the mold. Production obtained in a given day, the efficiency of that production in a modern molding plant having the latest equipment and using the proper material is again due to the mold. So, therefore, it is our motto—and we hope that it is adopted by all molders—that "The Best Mold Is The Cheapest".

Now what affects the cost of the mold: **Material**—material is basically in 90% of the molds made approximately 10% of the total cost. On that basis, certainly a saving of 10% in using inferior materials is definitely foolhardy. A molder should approach a mold not on the basis of what it costs, but what is the best mold for him to produce his product faster and better, so that today many people are giving consideration to materials that cost considerably more such as beryllium copper because of the cycle advantage that that material offers.

The type of mold to be used is of utmost importance, and has a great deal to do with the variations in mold prices that are received today. Customers coming to mold makers lack definite information as to what they want. The handling of the purchase of molds strictly through the purchasing department on a price basis is penny-wise

*This paper was presented at the recent SPI Plastics Conference in French Lick.*

and pound-foolish, unless there is an exceptional purchasing agent who is a trained mold designer or has a background in tool work—and this gentleman is a rare one and hard to find.

When a molder arrives at the mold maker's plant and places an item on the desk stating that he would like to have an 8-cavity mold to produce that part and of course adding that he wants it as quickly as possible, his request is no different than the person going to a contractor and saying, "I want a house". So he wants a house. How many rooms, whether there will be any bathrooms, the attic to be finished, is there a fireplace, does he want a garage, central heating system, does he want air conditioning?

## Important Questions

All these questions must be answered before the contractor can give the potential customer any indication of a price. This is the same with a mold maker. Are the cores to be cooled, is it to be an automatic, unscrewing mold, or a hand-core mold, are the cavities to be made out of prehardened steel, the type of finish that is required, is it vapor-honed finish or a highly polished optical finish, is the cooling to be through the cavities and cores or in the chase plate, is the holder to be designed ruggedly to stand up under pressure in high production? All these questions must be answered and unless they are definitely spelled out, then you can never hope to have any semblance of uniformity in price quotations received from more than one mold maker.

With the above factors determined, there are still other decided points that must also be considered that have a great bearing on the utimate cost of the mold.

**Tolerances**—are we trying to work at a tolerance in the molded piece of .001. If so, it is definitely impractical, if not impossible. The mold maker can make a mold with tolerances of .00001. The closer the tolerance, the longer it takes and the higher the cost. But in attempting to mold a piece at .001 the article can vary tolerance-wise from one color of material to another, or from one day to another. Humidity, temperature, molding pressure, any number of factors can affect this to the extent that the article cannot be held to that close tolerance.

It was stated by one of the speakers here that the molder should figure on a 70% factor. A 70% factor is sound providing the tolerances are sound in turn. If the tolerances are practical like plus and minus .004 or .005, then that factor certainly is reasonable. Going lower than that, this factor must be changed so that arriving at a .001 in a multiple cavity die, it should be reduced to a 10% factor. Even if that is possible.

**Taper or Draft**—those who have molded containers of any size or shape, recognize the importance of draft. As a matter of fact, draft is needed on all molded articles. The less draft, the more trouble in sticking in ejecting the piece. Also, the more cost to the mold maker in his attempt to get an operative mold. The more cost to the mold maker, the more cost to the molder.

**Automation**—today everything must be automatic. If a mold is to run automatically, it must be the very best mold that can be possibly produced because if there is any reason for the article not to eject from the cavity or off the core, even once out of every 10 shots or more, then the mold and machine cannot run automatically. But in doing this, you have an extra high precision tool and if you must run automatically, certainly that's the trend, you must figure on higher mold cost because once the mold is initially completed, there is still a lot of work that must be done on it to make it automatic. An automatic machine is not the answer—but a mold that will run automatically, is.

**Terms or Credit**—is a very important part of the over all consideration of a mold maker in his ultimate cost and price to the molder. Different than most operations, the mold maker orders his materials when he receives the order. Within a 30-day period, he must pay for it. When the order is started in his plant, his engineers and tool makers must be paid on a weekly basis. However, delivery of the mold may not be for three to four months and after the mold is delivered, regular terms are 30 days which means in many cases the mold maker has expended money for both labor and material, 4—5—and 6 months in advance and has extended credit literally during that length of time.

The burden of this expense hangs very heavily on the mold maker. Generally he must borrow capital for operating expenses and thereby pay interest. It is my opinion that a deposit is in order, or payments made on a monthly basis on a percentage of the material and labor expended with a balance held, if need be until the mold has been proven or delivered. The mold maker will give preference on both price and delivery to the molder who pays promptly and who assists by paying in advance. That type of customer is much in demand and the mold maker will literally turn "hand springs" to find him.

**Profits**—much has been said on how lucrative the mold making business is. It was said today in talks made by some of the panel that a 10 or 15% profit should be realized in molding but that the actual profit was less. In a meeting recently held of a mold makers' group (what I would consider a group of the finest mold makers in the country), there was not a single mold maker who made over 5%. This was before taxes, not after.

## Designing Costs

There is much that a mold maker contributes over and above what is the general impression of the plastics industry as a whole. Designing of molds is done very economically and generally at cost, or less. There are very few highly-trained engineers, graduates of technical schools like M.I.T., who can sit down and design molds as they must be designed today unless they are thoroughly trained, and if they could, the cost of employing them would be prohibitive.

Molds are tested by many mold makers, generally without any additional consideration and yet the cost of the molding machine which is never run in production, must be written off. The additional work required to make a mold run at some given cycle which was estimated by the molder and never guaranteed by the mold maker, the addition to the design of the mold calling for additional knockout pins or additional draft to make the piece eject often times is not acknowledged as a molder's responsibility but put back into the lap of the mold maker even though the design of the mold was approved by the engineering department of the molder. (The changing of the gates, the opening up of same, etc.) With the exception of the mold testing, much of this intangible cost that must be included in mold prices could be eliminated if an understanding of the mold maker and molder's responsibility was clearly defined and understood.

Great strides have been made in this direction by the setting up of a set of terms and conditions sponsored by the Society of the Plastics Industry and formulated by a group of mold makers with the approval of a representative group of molders from the same Society.

# Safety Procedures

# In the Reinforced Plastics Plant

J. Robert McCullough
*Safety Department, The Budd Company*

IN OUR PLASTICS DIVISION we work with both the polyester and the epoxy resins; therefore, we have both fire and toxicity hazards. With the polyesters the prime hazard, of course, is the fire hazard with a minimal toxicity hazard. Conversely, with the epoxies dermatitis is our prime consideration although the fire aspect can not be completely ignored.

Our control of these problems starts long before hazardous materials ever reach our plant. A formalized procedure has been established whereby only those hazardous materials as already approved for a specific use and appearing on a "Hazardous Materials List" may be purchased. This list was originally compiled by the safety department and any materials to be added to this list must be reviewed by us from a standpoint of both fire and toxicity and are then approved or disapproved for purchase. It is the responsibility of the safety department to keep this list active and up to date.

When these materials arrive at the plant they are placed in an isolated storage area under rigid control so that even though some difficulty might be had with them, they are away from the general plant, its personnel and its activity.

The amounts of these materials which may be brought into the general plant area are specifically limited in quantity and in no case de we permit more than a single day's supply of material to be brought into the working shops.

These procedures make it possible for us to know how much of what materials are in the plant and for what purpose so as that we cannot get into difficulty from sheer ignorance.

## Reinforced Hand Layups

Our primary use of polyester resins is in hand layups of this material reinforced with fibreglass mat. The resin mix itself as well as the monomers and accelerators used with it range from "explosive" for cobalt naphthenate and methyl ethyl ketone peroxide down to "flammable" diallyl phthalate. While some people may be sensitive to the action of the fibreglass mat and some others may be sensitive to styrene or even polyester resins we think of these as isolated cases which can be easily handled and concentrate our effort on fire prevention.

All of these ingredients are handled and mixed by trained specialists in an explosion-proof room. Not only are these mixes prepared in this room, but the closed tank systems employed in spraying the material are also charged in this room and delivered by the mixing technician to the point of fabrication. At this point of fabrication giant exhaust hoods are used to draw over-spray out through a system of fibreglass filters to the outside air. The c.f.m. is so great that a make-up system had to be installed on the opposite side of the room. The operators on this work are provided with cover-alls and rubber gloves to completely protect the body from contact with the material. It is also of interest that in conjunction with our plantwide 100% eye protection program that these people also wear eye protection. Also in this fabricating area complete fire protection is afforded with sprinkler systems, chemical fire extinguishers, deluge personnel showers, and fire blankets. It goes without saying that smoking is not permitted in the area.

## Overcoming Small Fires

We have occasionally had small fires due to the exotherm of unreacted trim material which had been thrown into waste cans in quantity and then "kicked over" in the can. This was overcome by reducing the size of the waste containers and by removing them more frequently.

On the basis of this control we have been working with large quantities of polyester materials for several years and have not had any serious problem.

Epoxy resins are used where bulk, rigidity and dimension maintenance are important. As compared with polyesters activity, our only fire concern is with acetone, and with the control program as outlined in conjunction with the polyesters we have managed to stay out of trouble. With toxicity, however, or to be more specific, with dermatitis, we have not been quite so fortunate. We have attempted to keep up to the minute in this field and we feel that we have had as much success as anyone in the field but it is a fact that we have had some dermatitis difficulties.

People who work with this material are given a physical examination prior to entering the department. Persons with known skin sensitivities or already afflicted with one form of dermatitis or another are naturally eliminated. There are some sources that advocate patch testing at this point but there are many and divergent opinions as to the effectiveness of patch testing and we are among those who consider that it still leaves much to be desired. We know

that these materials, and primarily the amine hardeners, are both basic irritants and sensitizers, that their resultant defection is a contact dermatitis and we seek to prevent the contact. We provide personalized cover-alls and by personalized I mean that several pair are assigned to each employee so as that he is always wearing one pair of his own while the other one or two pair are being laundered. These cover-alls have detachable sleeves which are an expendible item. We have used a light-weight duck but are currently experimenting with a disposable paper. We also use a close fitting rubber glove that is rugged enough for the work involved yet light enough to permit setting and forming with the fingers.

Additional prophylactic measures are taken such as separate lockers and toilet facilities for plastics workers. Double lockers, one for street clothes and one for work clothes; protective creams of which we have tried dozens. We currently believe that Kerodex is the most effective as a barrier cream for these materials. Also special waterless soaps are supplied and the use of acetone on the skin is forbidden. Our effort obviously is not only to prevent contact with these irritants but to remove as little as possible the natural oils and protective horny surface of the skin. To further control this material a separate mixing room similar to the one for polyesters work is maintained but for a different reason. Here an experienced employee, who over a period of the last five years has shown himself either through personal cleanliness or a natural resistance to have proven impervious to the irritating effects, mixes and supplies the basic resins for the manufacturing processes and gives them to the floor mechanics and quantity and condition ready to apply to the job. It minimizes the employee exposure.

Hand work on these build-ups begins while the material is actually partially cured although we refer to it in shop terminology as being in the cured state. To minimize hazard here we again fall back on a giant octopus of an exhaust system which does not move the c.f.m. of our polyesters exhaust but does filter the air and remove toxic and or irritating dusts from the work area.

## Isolated Out-Breaks

With the extensive effort that we have made to control the use of this material one would think that we should be completely trouble-free. The fact of the matter is that while we have minimized our difficulties we still have isolated out-breaks of industrial dermatitis. What then is our outlook towards complete eradication of this difficulty?

First, we must look to you people of the plastics engineers group to find harmless materials to do the same work. We have but recently changed in a large part to a supposedly minimal irritating hardener. As yet it is too soon to state any concrete results but we feel that in this direction lies the ultimate complete solution even if it means overhauling the entire chemical structure of the process.

Another very important phase is in continuing to sell to the production people the idea that personal cleanliness is the most important key to the control of this dermatitis. It is a difficult situation because the average man thinks you are calling him dirty when you talk about personal cleanliness. Yet, every text that I have been able to read on industrial dermatitis stresses personal cleanliness as the most important factor in its prevention.

## Vinyls in Styrene . . .

(Continued from Page 18)

tained strength would be expected to appear almost independent of the original flexural strength.

Figure V includes sheet extruded by ten suppliers from five different raw material sources, and thus should be representative of commercially produced sheets.

Since such a variation does exist among sheets of polystyrene, a minimum value of retained strength could not be established for specification purposes. However, since a given sheet is uniform, comparison tests can be made easily and would be adequate for most applications.

The test described here has eliminated the objections to the previous tests. The reproducibility showed that variation within each polystyrene sheet made from a specific grade of impact polystyrene is negligible; the test is quantitative rather than qualitative; and the time of exposure is two hours instead of three weeks in the test described previously or at least four days in the contact marring test.

TABLE IV

Various Styrene Sheets With One Vinyl

| Supplier | Parallel (p.s.i.) | Perpendicular (p.s.i.) |
|---|---|---|
| A | 7200 - 7500 | 6300 - 6700 |
| B | 6100 - 6500 | 5700 - 6400 |
| C | 6800 - 7400 | 6600 - 6700 |
| D | 5800 - 6800 | 5700 - 6300 |

Figure 4

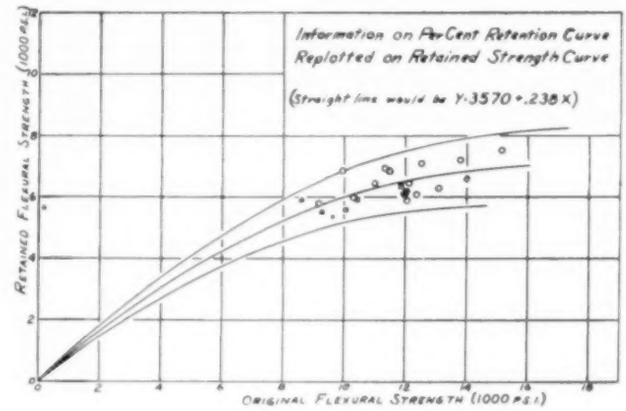
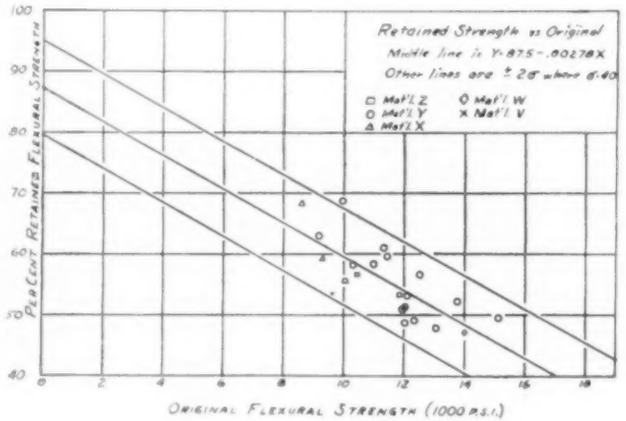
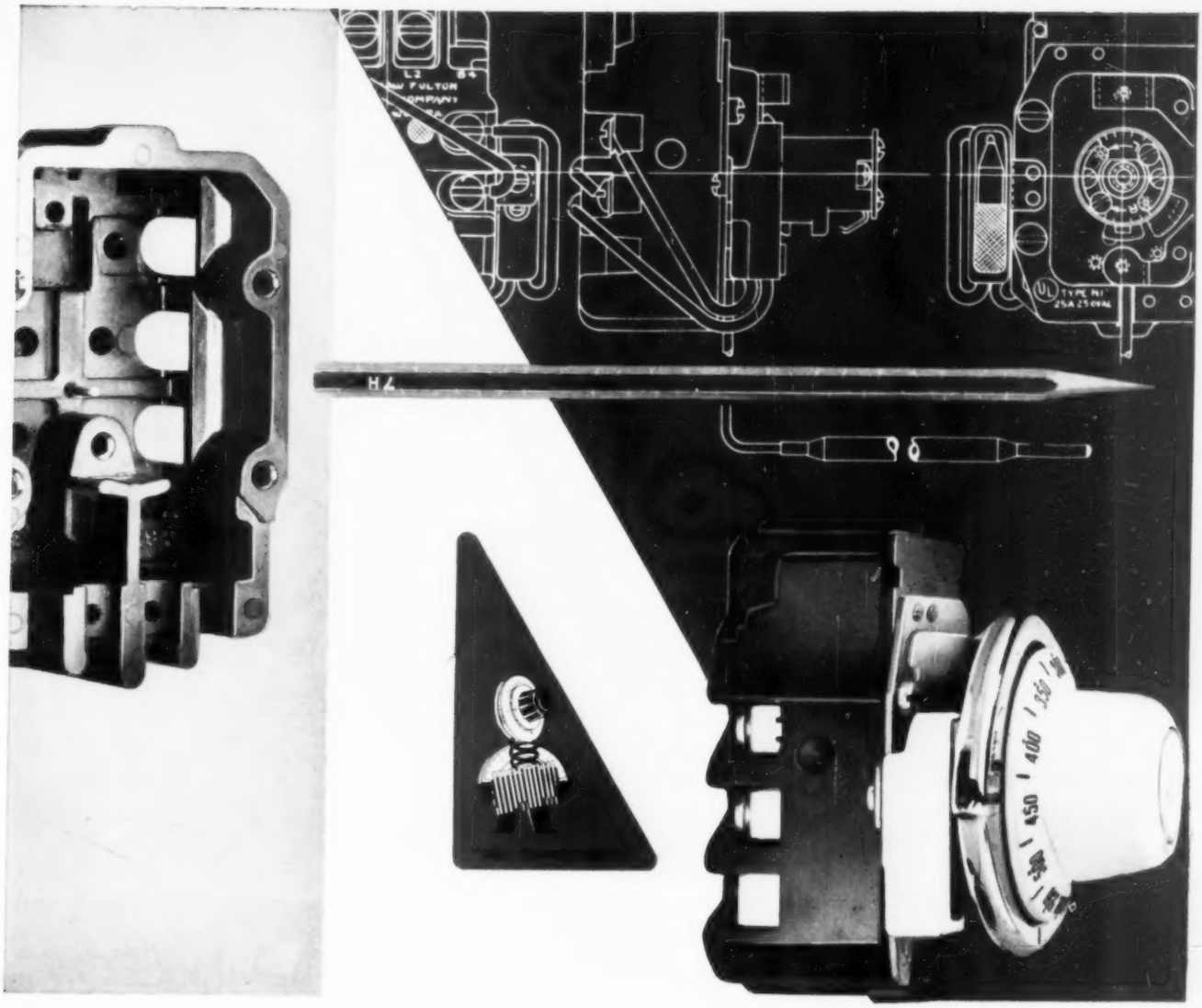

Information on Per Cent Retention Curve
Replotted on Retained Strength Curve
(Straight line would be Y=3570+.238X)
Retained Flexural Strength (1000 P.S.I.)
Original Flexural Strength (1000 P.S.I.)

Figure 5


Retained Strength vs Original
Middle line is Y=87.5-.0027BX
Other lines are ± 2σ where σ=4.0
□ Mat'l Z
○ Mat'l Y
△ Mat'l X
◇ Mat'l W
× Mat'l V
Per Cent Retained Flexural Strength
Original Flexural Strength (1000 P.S.I.)



## it's DURITE for Robertshaw-Fulton thermostats

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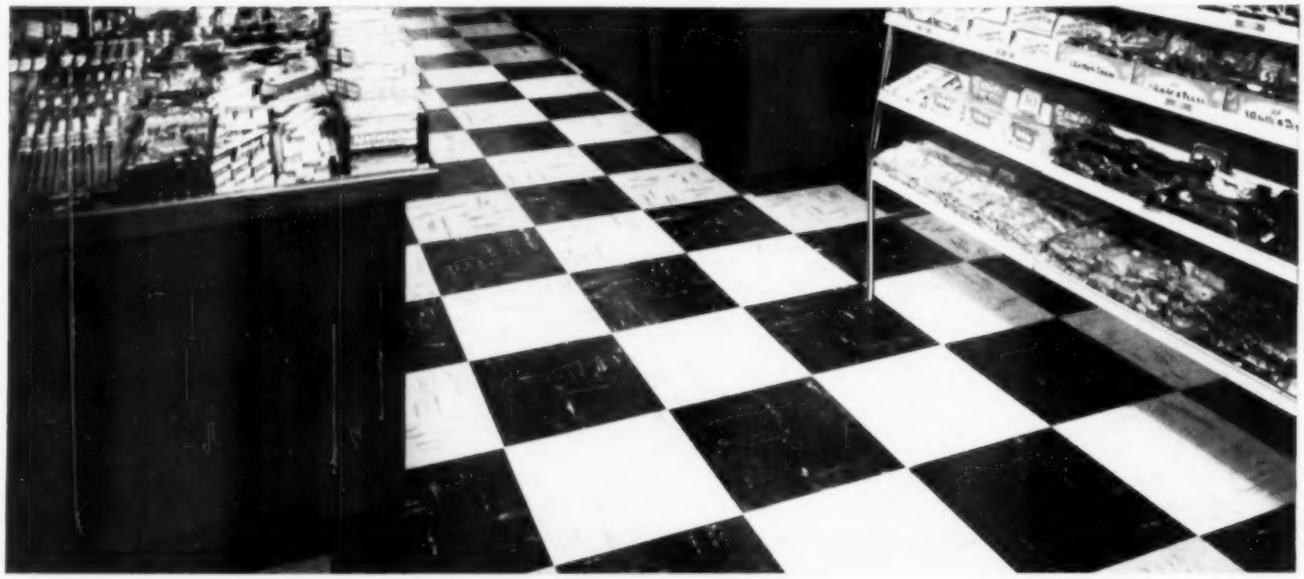

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# SOCIETY OF PLASTICS ENGINEERS, INC.

NATIONAL EXECUTIVE OFFICES, SUITE 116-18
34 EAST PUTNAM AVENUE, GREENWICH, CONNECTICUT

Dear SPE Member:

Several weeks ago I ran across a story of a perspicacious executive who told a group of engineers the following:

> "Assume you invest in a society membership of one source or another. Now, gentlemen, if you do no more than tell your Boss that you belong to this society; if you do no more than read the title in the Society Journal; if you do no more than read the title and abstracts of the technical articles in the books supplied by the society; if you no more than attend a few meetings a year of the society's local chapter, you would have to be a pretty lousy engineer not to have picked up enough information, news and interest to have earned that membership fee over and over again."

It makes sense, doesn't it? Yet there are many of your associates who have not taken advantage of the opportunity afforded them through membership in our group.

The objects of the Society (a non-profit organization) are to promote the Arts, Sciences, and Engineering practices and standards connected with the utilization of plastics. In plain, everyday language, we are working for the recognition and advancements of plastics and by so doing can offer to our members a means of keeping pace with this growing, ever changing industry through meetings, personal contact, and publications. Today better than 5000 members have the opportunity to meet monthly through 35 geographical section chapters. The stature of the National Technical Conferences is attested to by the fact that last year 2500 individuals heard a series of outstanding papers and met with their colleagues to exchange ideas.

Whom do you know that is not presently a member and who owes it to himself to join? Won't you send him your copy of this Journal right now? Point out our appeal for new, qualified members; and invite him to attend the next local chapter meeting. You'll be doing him, yourself, and the Society a real favor!

Sincerely,

Dick Beckwith

R. W. Beckwith, Chairman
National Membership Committee

# NEWS of the industry

## Escambia Name Change

The new corporate name and the location of permanent offices for Escambia Bay Chemical Corporation were announced today by R. U. Haslanger, president.

The corporation discontinued the use of the word "Bay" in its official title today to become Escambia Chemical Corporation.

The executive offices of the corporation now occupy the twentieth floor at 261 Madison Avenue, New York. Offices of the president; the resin sales manager, W. W. Peacock, Jr., and the commercial manager, A. N. Wohlwend, are all located at this address.

The corporation's research and development is located at Cambridge and Newton, Massachusetts, under the direction of Dr. N. C. Robertson, vice president.

Production facilities are located at Pensacola, Florida, under the direction of D. J. Stark, vice president.

Escambia Chemical began commercial production of ammonia, nitric acid, ammonium nitrate and nitrogen fertilizer solutions at its Pensacola plant last year. The sales agency for the firm's nitrogen fertilizer products is Asheraft-Wilkinson Company; Trust Company of Georgia Building, Atlanta, Georgia.

## Plymouth Elects Officers

Plymouth Industrial Products, Inc. of Sheboygan, Wisconsin, which is a manufacturer of low cost plastics of the thermoplastic type, made public the Annual Stockholder's Meeting held on July 17, 1956 at the Company's Sheboygan Plant. The following were elected to membership on the Board of Directors for the ensuing year: Aldred J. Simmons, Thomas B. Gibbs, Gerard W. Mulder, William E. Haack and Clifford R. Palmer.

Following the Stockholders Meeting, the Annual Board of Directors Meeting was held, at which time the following officers were re-elected: Aldred J. Simmons, President; Thomas B. Gibbs, Vice-President; Gerard W. Mulder, Vice-President; William E. Haack, Secretary-Treasurer; and Robert W. Suckow, Assistant Secretary-Treasurer. Clifford R. Palmer was elected a Vice-President of the Company in addition to the position of General Manager which he now holds.

## 3M's Buys Zenith

Purchase of Zenith Plastics Co., local producer of highly specialized aircraft components, by Minnesota Mining & Manufacturing Co. for $4,000,000 was announced.

Milton Brucker, president of the Gardena firm, and Herbert P. Buetow, 3M president, described the transaction as one that would provide "tremendous mutual benefits" without altering Zenith's management and policies.

3M's financial backing and the assistance of its excellent research team will enable Zenith to realize its full potential.

## Resinous-Reslac-Pioneer

Domestic and foreign holdings of Pioneer Latex and Chemical Company have been acquired by the Borden Company's Chemical Division. The Middlesex, N. J., firm—manufacturer of protective coatings and other products for the textile, flooring and adhesives industries — will be merged with Borden's Resinous-Reslac Department.

The announcement climaxed negotiations begun last year. An undisclosed amount of Borden stock was exchanged for Pioneer's assets — a plant in Middlesex and an interest in Placco Puerto Rico and Placco Colombiana Ltda.

Augustine R. Marusi, a vice president of the Borden Company and president of its Chemical Division, said the merged units will be known as Resinous-Reslac-Pioneer.

"Products of the two are complementary," he said, "and this new move enables us to offer a more diversified line. It gives us a Resinous-Reslac plant in the New York area and this, with our contemplated expansion in the South and West, will round out geographical coverage; hence, better service to customers."

## Klauder Machines

A new and greatly simplified machine for making both rigid and flexible polyurethane foams is now being offered by the Klauder Williams Company, the result of research and development by two long established companies—The Klauder Weldon Giles Machine Company of Philadelphia, Pennsylvania, specialists in the fabrication of stainless steel equipment, and Gabriel Williams Company, Research Chemists of Brooklyn, New York.

These new machines will soon be offered in various capacities from large production models to small portable units for pattern and development molding.

All machines can be easily set to produce either flexible or rigid polyurethane foams with a wide range of properties to meet the need of a multitude of end uses.

The machines are designed so that the flow of the two components is easily regulated to produce a wide range of end results. The components are placed in separate tanks above the top of the machine and gravity feed to the pumps eliminates all problems of priming. Positive displacement pumps driven by variable speed drives permit exact proportioning of the basic components prior to entering the mixing head. With this mixing an exothermic reaction takes place and $CO_2$ is given off causing controlled foaming of the product as a result of the reaction. No additional whipping or frothing is necessary as is so often needed in the production of other types of foam materials. The mixed material may be immediately fed into molds.

## New Oscillator

Silver ribbon, molded with great precision in SUPRAMICA 555 ceramoplastic, is utilized in a newly developed oscillator for the Signal Corps, to provide crystal stability without the use of a crystal. This important new development will eliminate dependence on crystals for oscillator tuning stability, and make possible greater accuracy at lower cost, according to Mycalex Corporation of America, producers of the ceramoplastic, and Crosley Division of Avco Manufacturing Company, designers of the tuning unit.

## American Agile Booth

A unique opportunity for visitors to the 9th National Chemical Exposition to bring sample targets for corrosion-resistant coating will be offered by the American Agile Corporation at its booth (Number 1), during the week of the show, November 27 to 30, at Cleveland's Public Hall.

Believed to be the first time that an exhibitor has maintained such a service, Agile will coat one or two sample targets of a company's own production items with either polyethylene, nylon or fluorethene corrosion-resistant material.

The company states that such targets must be limited to lengths up to six inches, with widths or diameters up to two inches. However, with such targets so coated, a company representative can then return home and evaluate the coatings in terms of his own requirements.

# Industrial Literature

## Air Force, Navy Reports

A report for the Air Force dealing with the permeability of polyethylene and another for the Navy concerned with plastic plates have been released for use of industry through the Office of Technical Services, U. S. Department of Commerce.

**Theoretical investigation of the mechanics of transfer of materials through polyethylene.** H. A. Bent, University of Connecticut, and J. Pinsky, Plax Corp., for Wright Air Development Center. Aug. 1955. 93 pages. $2.50. (Order PB 121194 from OTS, U. S. Department of Commerce, Washington 25.) Equations for permeability of polyethylene are established, along with master plots for interpolating homologous materials and extrapolating for temperature changes. A bibliography is included for permeability, solubility and diffusion in polymer systems.

**The theory of plastic plates.** W. Prager, Brown University for Office of Naval Research. Jan. 1955. 24 pages. 75 cents. (Order PB 111943 from OTS, U. S. Department of Commerce, Washington 25.) Problems concerning circular plastic plates under rotationally symmetric conditions of loading and support are discussed. The report serves as an introduction to a number of recent, detailed papers and reports on the subject, some of which are not readily accessible.

## West Instrument Bulletin

3-position pyrometer temperature controllers are now being offered for many applications by West Instrument Corporation of Chicago. These controls are easily wired for a wide variety of specialized control applications: heating with automatic cooling; motor operated fuel valve; Hi-Lo-Off or Hi-Lo-Med electric or fuel systems; control with High Limit feature and automatic reset.

These new West instruments are said to eliminate costly manual control and reduce spoilage of product and deterioration of equipment. They are used with plastic extruders, industrial ovens, furnaces, etc. They provide for two types of neutral band, each with two types of control.

One, with a single setting pointer, permits no more than 1% of scale range as neutral. The other, with two settings, permits spread up to 20% of range. On-off or proportioning type control available. All models are free from vacuum tubes.

Details are listed and shown in Bulletin JT-1 which is available from any West office, including factories at Chicago and Brighton, England.

## Emery Industries Booklet

A new 20-page booklet titled "Empol 1022 Polymerized Fatty Acid" has recently been published by the Organic Chemical Sales Department of Emery Industries, Inc.

In addition to a complete description, specifications, characteristics and shipping data on Empol 1022, the booklet contains considerable application data in many fields. These are exemplified by adhesives, films, foams, lubricants, elastomers and surface coatings.

A complete end-use bibliography completes the material presented.

For a copy of this booklet titled, "Empol 1022 Polymerized Fatty Acid" write: Emery Industries, Inc., Dept. 5, Carew Tower, Cincinnati 2, Ohio.

## Mixing Mills

A new bulletin, "Farrel-Birmingham 6" x 13" Laboratory Mills for Rubber and Plastics," is now available on request to the company's headquarters, Ansonia, Connecticut.

Aided by illustrations and line drawings, this 12-page booklet concisely presents all information necessary to determine from six standard models offered, the most suitable mill for any individual requirement.

## Silicone Rubber Reinforcement

Silicone rubber has been successfully reinforced with carbon black, previously effective only with hydrocarbon rubbers, according to a report of recent research for the Air Force released to industry through the Office of Technical Services, U. S. Department of Commerce.

During tests on a new silicone polymer, Linde W-96—a dimethyl siloxane modified with a small number of active vinyl groups on the side chains—carbon black was introduced as a filler after the gun was vulcanized with di-tertiary-butyl peroxide. A firm, well-reinforced rubber was produced.

Prior to the experimentation, carbon black fillers had hampered curing action, evolved gas at high temperatures, and provided poor reinforcement in silicone rubber. Only the so-called "white" fillers, such as silica, calcium carbonate, and titanium dioxide, produced satisfactory reinforcements.

The report, PB 121231 **Reinforcement of Silicone Rubber with Carbon Black,** A. J. DeFrancesco, Connecticut Hard Rubber Co. for Wright Air Development Center, Feb. 1956, may be ordered from OTS, U. S. Department of Commerce, Washington 25. It contains 33 pages, price $1.

## Vinyl Acetate Properties

A new 20-page bulletin on vinyl acetate monomer has been published by Air Reduction Chemical Company, a division of Air Reduction Company, Inc.

In addition to essential information on physical properties, grades, specifications and handling, the bulletin also includes details on polymerization and chemical reactions of vinyl acetate monomer. All data is fully referenced.

For your copy, write to Air Reduction Chemical Company, A division of Air Reduction Company, Inc., 150 East 42nd Street, New York 17, New York.

## Dielectric Ovens Material

Young Brothers Company of Cleveland, Ohio, pioneer manufacturer of baking, drying and heat treat ovens, announces a complete new line of dielectric ovens suitable for heating, baking, drying and curing a wide variety of non-metallic materials. Five basic models are presently being offered with output ratings of 15 KW, 30 KW, 60 KW, 75 KW and 150 KW, each.

Bulletin No. 56-E illustrates and describes the new Young Brothers Dielectric Ovens. Copies may be obtained by writing Young Brothers Company, Dept 19, 1831 Columbus Road, Cleveland 13, Ohio.

## Hull-Standard Presses

Hull-Standard Corporation, Abington, Pa. offers bulletin No. A-456 on their new line of Completely Automatic Compression Molding Presses available in 50, 75, 100, 150, 200 and 300 ton sizes.

High production at low cost, flexible feeding mechanism, Quick-set cycle control, safety interlock of all functions and other features are illustrated and described.

## Census Report Available

The advance report, 1954 Census of Manufactures, Plastics Materials Industry, 5 pages, is available for ten cents from the Bureau of the Census, Washington 25, D.C.

# THE INJECTION molderscope

By A. R. Morse
*President, Injection Molder's Supply Co.*

## Free Enterprise

Every injection molder should contribute to the Foundation for Economic Education, Irvington-on-Hudson New York. This worthy group is plugging for free enterprise — the kind of initiative that has sparked the chief growth and development of injection molding in particular which sprang largely from modest beginnings and individual savings. Five dollars, (deductable for tax purposes) will bring you "The Freemen," and other literature to distribute to your employees for educational purposes. Here's a worthwhile quote from "The Freeman" for May, 1956:

"The dynamic economy of this country, which has brought our living standard to a point where it is the envy of even the richest other nation in the world, was created by the incentives of free competition, by risking capital, by allowing a citizen to be rewarded according to his **work** instead of adopting the communist principle of rewarding each 'according to his **needs.**' The growth of the progressive income tax has imposed a limitation on the American competitive system that can, in the end, destroy that system and replace it with a Marxian society that levels all people off in legislated poverty."

## Saturable Reactors

Heating cylinder performance when saturable reactors are used, is far superior to results obtained even with the finest proportioning pyrometers. While these controls have been on the market for some time, they have now been simplified to the point where they are applicable both price-wise and engineering-wise to the injection industry. These controllers have the advantage of continuous, but of course, variable heat output. By eliminating both the original cost and the maintenance expense of the present off-on contactors which must always be used with conventional pyrometers, they in part justify their considerable extra cost. We tested a saturable reactor setup last year against the best proportioning pyrometer, with the usual on-off contactor. No matter how closely we tuned the pyrometer, the saturable reactor consistently put heat into the cylinder more smoothly. The "hunting" of the pyrometer was eliminated and the probe disclosed that measurably more constant heat was reaching the plastic. The few saturable reactors now in use already point up a trend. I predict that in a few years most new machines will be equipped with these superior new controls. Both Wheelco and Taco-West are currently offering this type of instrument where extremely close control is advisable.

## A Vinyl Cylinder

For two years we have been trying to perfect a quick disassembly cylinder designed expressly for vinyl materials. The design is such that the heater can be quickly unscrewed in the field for cleaning. We finally evolved a (patentable ?) register design for a threaded cylinder that has a guide or aligning rim or lip which is separate from the inside register, but which still holds the joint true without picking up on itself, or binding the threads. While this register design was ready some time ago, it still seemed apparent that something was lacking—that present heat controls were too crude for vinyl. (This led to our testing saturable reactors which offered a great deal closer heat regulation.) Something MORE, however, was still needed for vinyl molding than just a quick cleaning heater. Ken Rouzer of Gatx, gave us the necessary clue when he designed a cylinder with a hollow, oil-heated spreader for Kel-F. His oil-heated spreader proved to be the answer we were searching for. By using electric heat on the outer body, we get the high melting capacity you cannot get from oil alone. And by circulating hot oil through a hollow spreader, we can quench, and control, and even cut out the harsh effect of the normal high heat input from the bands. When combined with the threaded heater, the use of oil heat has given us the first real clue to a correct technique for vinyl molding. The new heaters are expensive, but outperform anything ever developed for vinyl before. Like any highly specialized product, they require know-how to assemble and operate. The cylinders are put together with huge wrenches, and alemite fitting holes are provided to shoot the threads full of penetrating oil before disassembly.

Now I am not cutting loose with this blast just because the heaters are an IMS Product as you might suspect, but for other reasons:

First, I have predicted that development of special purpose cylinders is inevitable, and this to the best of my present information, is the first heating cylinder ever developed from the ground up especially for handling just one specific material type.

It is quite possible to safely and profitably injection mold vinyl plastics, but refinements in design and control of present heaters are essential.

The use of saturable reactors on vinyl cylinders is definitely recommended, and I understand a few new machines are now coming through with this type of control especially equipped for vinyl work.

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**The Injection Molderscope solicits articles on any phase of injection molding from anyone who has ideas he wants aired. We want stimulating articles and comments from anyone that can be adapted for publication. So let us hear from you — on machinery, on powders, on molds — it is your chance to be heard.**

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## Elmer E. Mills opens Plastics Consulting Office

Elmer E. Mills, prominently identified with the plastics manufacturing field in Chicago for approximately 30 years, has opened an office at Room 1040 Field Building, 135 S. La Salle St., Chicago (Tel. Central 6-9677), where he will serve as a consultant on all phases of the plastics industry. Mr. Mills, who opened his own plant in 1937, pioneered the custom molding of plastic parts by the injection process in the Chicago area. Later he developed a successful method of producing flexible polyethylene containers and became a major supplier of these lightweight, non-breakable packages. In 1953, upon purchase of his plant by Continental Can Co., Mr. Mills was retained by the company in an advisory capacity, a position which he held until July 31, 1956.

# AROUND THE WORLD

## UNITED STATES

### RUBBER AGE

### August, 1956

Abstracter: James Harrington

**"PROPOSED TENTATIVE SPECIFICATIONS AND METHODS OF TEST FOR FLEXIBLE URETHANE FOAM" —pg. 803-810.**

The proposed tentative specifications and test methods for flexible urethane foams are printed in their entirety. Test descriptions include humidity aging, compression set, deflection, flexing, tensile strength and elongation, density, tear resistance, and flammability. This material was prepared by the Flexible Urethane Foam Test Methods Subcommittee of the SPI Cellular Plastics Division.

## FRANCE

### INDUSTRIE DES PLASTIQUES MODERNE

### Vol. 8, No. 7

Abstracter: Hans Mayer

**FLEXIBLE TANK FOR THE STORAGE OF HYDROCARBONS.**

The design, construction and assembly of a storage tank, formed from thermoplastic sheet material, is described.

**PRINTED CIRCUITS—H. Debroise.**

After the application of this technique for mass production in the U.S.A. has been discussed, the author points out that printed circuits lend themselves for certain small production runs as well and cites the following reasons: size and weight advantages compared to conventional wiring, saving in assembly time, reduction, even elimination of control and supervision of the assembly due to the automatic alikeness of the printed circuits, savings in the setup of assembly lines. The different methods employed in the manufacture of printed circuits are enumerated.

**USE OF POLYETHYLENE IN THE PACKING OF FOOD—M. Perraud.**

Polyethylene is used in the wrapping of foods either in form of film or in form of coating applied to either paper or metal foil. Besides this application, polyethylene finds use in the form of bottle or container shaped devices in the storage of processed foods or is being used as part of composite food dispensing devices in the form of closures, dispensers, etc. Due to being non toxic the possibilities of using polyethylene in connection with foodstuff is almost unlimited. A ver complete list of tests regarding chemical reactions has been added to the article.

## GREAT BRITAIN

### BRITISH PLASTICS

### Vol. 29, May, 1956

Abstracter: Evert A. Mol

**SILICONES FOR THE PLASTICS INDUSTRY—Pages 158-161**

Silicones are now made in U.K. by Midland Silicones, Ltd. (an associated company of Dow-Corning and Albright & Wilson), at Barry, South Wales and by the Nobel Division of I.C.I. at Ardeer in Ayrshire (under G. E. license). The usual selection of materials are made, as rubbers, fluids, dispersions, and molding resins. They are used as foam inhibitors, lubricants, high temperature dielectrics and lacquers, paint additives, water-repellents, textile and leather finishes.

**RAM EXTRUSION OF GRANULATED P.T.F.E.—Pages 168-170**

Ram extrusion of P.T.F.E., (Teflon in United States), is preferred over screw extrusion because it gives better control. At least 5 variables must be accurately controlled.

(A) **The Temperature.**

This is a difficult point because of the poor heat conductance. The workable temperature range is not too large. It must be between the transition temperature of P.T.F.E. (327°C) and the decomposition temperature (430°C).

(B) **Ram Pressure.**

Ram pressure may not be too high because of the pronounced packing tendency of the molding powder. If packing occurs, cracks in the extrudate result.

(C) **Feed.**

The feed must be kept absolutely constant because differences in feed give variations in extrusion speed and consequently variations in cure.

(D) **Time Cycle.**

(E) **Forming Pressure.**

This is one of the most difficult variables to control. It results from two sources.

1. The friction in the die bore.
2. The restraining force that is artificially applied to the product at the nozzle.

Rigid control is required to insure a product of constantly good quality. Ultrasonics are used to check the density of the extrudate and to determine the presence of flaws.

**THE SHOCK CURING OF SOME LAMINATED MATERIALS — Pages 171-175**

**By C. A. Redfarn and J. Bedford**

In this process an electric current through the resin to be cured itself results in an almost instantaneous cure accompanied by a drop in current density. The process has been covered by British Patent 737,374, in an example given for the shock curing of so-called Durestos. The shock curing time was found to be about 5 seconds with an applied force of 250 V.A.C., the temperature rose to 160-200°C, the applied patent pressure was 200 per square inch. This is an astonishing speed-up when compared against the more than 3 hours required to perform the same cure under standard conditions. The process has its limitations. The resin to be cured must have a minimum conductivity to allow a current density of about .25 A sq. inch. Direct current should not be used because of polarization effects that can oppose curing. Electric grades of laminates can not be shock cured because of their high resistivity.

**CONSIDERATION OF SOME BASIC FAULTS IN POLYSTYRENE MOLDING — Part I. Heat Considerations—Pages 176-177**
**By Maurice Fuzzard**

Tabulation and a short discussion of the faults that can occur in injection molded polystyrene. Faults like poor weld lines, warpage, and short moldings are explained in terms of cylinder temperature and mold pressures.

**MODERN METHODS OF MOLD MAKING—Part IV. Materials, Heat Treatment and Vapor Blasting — Pages 178-182**

The fourth part of this series discusses the materials (steels) their requirements, (machinability, hardness after finishing, tensile strength, distortion), their compositions, (alloys of Fe with C, Mn, Cr, Ni). Considerable attention is given to heat-treating methods, (carbonizing, annealing), and to the so-called liquid honing process. This process is also known as vapor blasting or pressure jet lapping and it uses a slurry of a fine abrasive in water that is projected against the steel surface by compressed air.

**THE PRINCIPLE OF THE POTENTIAL COVERGENCE-DIVERGENCE AS FOUNDATION FOR RESEARCH IN DIFFERENT FIELDS — Pages 184-188**
**By Dr. M. S. Frenkel**

The editors of British Plastics would have saved the average not so expert reader a lot of headaches if this third article by Dr. Frenkel had preceded the two earlier ones on the subject of "Continuous imposed order Extrusion." Although rather difficult to read the article is interesting as a new and more or less abstract approach to engineering problems. The problem of convergence-divergence, including the features of similarity and difference are discussed; it is interesting to discover that the extrusion field can boast the same foundation as nuclear physics, waves and corpuscles, energy and mass, Maxwell's equations of electro-magnetism, subjectivity and objectivity, stability equations. The author introduces six factors to produce what he calls different combinations of intermixing in the mixer extruder discussed in parts one and two of the series that appeared in the February and March issues of British Plastics. Even this is not enough, for the author states that there are yet other series of variations not treated by him; for example that due to Corioli's acceleration whatever that may be. The whole series of very complicated prose is difficult to abstract, it simply has to be read. The realization of the ideas of Dr. Frenkel may not appear too attractive to practical engineers, the extra complication of rotating the external threads at different speeds may cause more trouble than it is worth. Frenkel states that there is no back flow in his machine but this is of course not true. This machine has the same back flow as any single screw extruder because of the fact that the threads in any position offer a continuous path for flow over the complete length of the screw. Also it is difficult to see how the weight of the material flowing into the extruder can help substantially to compensate the actual load on the bearings caused by the extrusion pressure. The weight of the material can be at best only a small fraction of the generated extrusion pressure.

## British Plastics
### Vol. 29, June, 1956

**POLYVINYL ALCOHOL FOAM FOR ARTERY GRAFTING — Kenneth Owen.**

Polyvinyl alcohol foam possesses most of the properties required by any foreign substance that is to be left in the body as an artery. It must be completely free of any toxic or irritant properties and must have a smooth inner lining upon which blood will not readily clot. The tube should have a porous wettable outer surface so that tissue fluids may permeate the material and tissue cells grow into it. The tubes must be strong enough to withstand the blood pressure and its pulsations and must not kink or wrinkle. Polyvinyl alcohol was first used 5 years ago in its uncompressed form. This was not completely successful but later arterial tubes were made by winding and compressing strips of foam around a mandril. The article discusses in some detail the construction of branched tubes and the method used to bring them into place in the human body.

**SOME PROPERTIES AND APPLICATIONS OF EPOXIDE RESINS—Anonymous.**

The sales value and a breakdown of their main applications is given with a discussion of the main applications as electrical applications, structural laminates, adhesives, glass fibers, and synthetic rubber systems. The epoxides are in the process of replacing polyesters because of their better stability under conditions of temperature and high humidity and the better adhesion to metals which results in a better hermetic sealing. For potting it has been found that the inclusion of fillers has improved the overall characteristics significantly. The best all-around filler has been found to be mica flour of about 200 mesh. It cannot be used in heavy concentrations, however, because of the fact that it raises the apparent viscosity to an unworkable level. For heavy concentrations silica sand of 200 mesh has been found to be much more satisfactory.

**CONSIDERATION OF SOME BASIC FAULTS IN POLYSTYRENE MOLDING — Maurice Fuzzard.**

The second part of Fuzzard's paper discusses stress, packing, and lubricants. The advantages and drawbacks of weight feed are discussed and preheating is given as a good method to reduce stress in the molding. Preheating also improves the heating capacity of the press and so speeds up the cycles. Lubricants can be either too little or too much, a newer development is so-called external lubrication which improves flow and need only be used in very small quantities of the order of 3 g per 100 lb.

## British Plastics
### Vol. 29, July, 1956

**MODIFIED VACUUM FORMING TECHNIQUE—Anonymous.**

A technique is described that is claimed to give a depth of draw hitherto unattainable. The technique originates in Switzerland where it is known as the Formvac airslip process. Its main advantage is that it cuts down on edge trim and thus reduces material cost. Furthermore, the weakening of the vertical walls is diminished. The idea behind the technique is the prevention of the sheet from blocking on top of the mold by causing the sheet to slip over the edge and down the vertical walls. The "lubricant" which permits this to happen is hot air maintained under just sufficient pressure to lift the heat-softened sheet so that it slips over the edge of the mold as it is pushed in.

**BERYLLIUM COPPER MOLDS — Anonymous.**

Beryllium copper alloys have unique physical properties that are of particular advantage to the mold builder. It can be easily cast or hobbed and its high thermal conductivity makes it possible to reduce the cycle times in injection molding. The article describes a multi-cavity mold for the production of spin curlers. In this particular case a 20% productivity over a steel cavity was obtained. The corrosion resistance of the alloy is sufficient for most plastics, for phenolic and vinyls, however, it must be plated with nickel or chromium. The alloy is quite hard and has a good wear resistance; runs in excess of 4 million have been successfully performed. The usual casting methods as sand casting, pressure casting, and investment casting can be employed to produce copper beryllium molds.

**EXTRUDING HIGH-DENSITY POLYTHENE—Anonymous.**

A profusely illustrated description of how to extrude polythene pipe on a Windsor twin-screw extruder using a sizing die. Material under dis-

**(Please turn to Page 52)**

# SPEAKING OF EXTRUSION

*Edited by* R. D. Sackett
Technical Service Associate
Monsanto Chemical Company
Springfield, Massachusetts

## Fundamental Mechanisms in Polyethylene Extrusion—Part I

B. H. Maddock
*Development Laboratories*
*Bakelite Company*

Fundamental extrusion theories, a number of which have appeared in the literature in recent years, are necessarily complicated in a mathematical sense. One of the simplest concepts is that which describes extruder output in terms of forward flow through the screw channel opposed by back flow through the channel and through the clearance between the thread and the cylinder wall. The forward flow is the volume of material which the screw will deliver at zero back pressure or with no head on the machine and is a function of the screw dimensions at the discharge end and the screw speed. Theoretically a volume equal to that of the last thread will be delivered with each revolution of the screw. In practice this amount is usually less than one half of the theoretical.

When flow is restricted by a die, pressure is developed in the head cavity. This pressure causes back flow through the screw channel and over the screw threads, opposing the forward flow and reducing the output rate. In a well designed screw, the back flow over the threads can usually be neglected. The back flow through the channel depends upon the channel dimensions, the viscosity of the resin and the magnitude of the pressure. An equation for the extruder discharge rate can therefore be written in the form:

$$Q = \alpha N - (\beta/\eta) P \qquad (1)$$

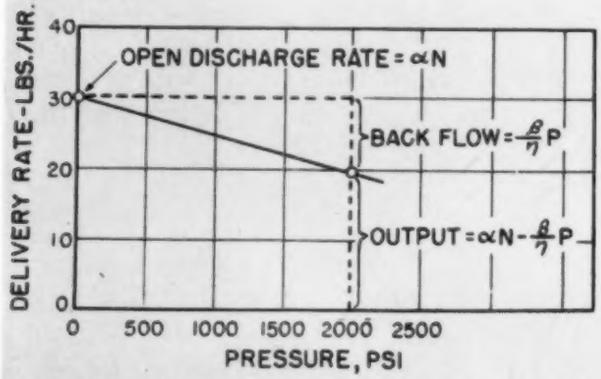
Forward flow — Back flow

where Q = volume rate of discharge
N = screw speed
P = pressure
$\alpha$ = forward flow constant (screw dimensions only)
$\beta$ = back flow constant (screw dimensions only)
$\eta$ = resin viscosity

Equation (1) is seen to be a straight line which can be represented as in Figure (1).

Operating characteristics of the extruder can now be fully described if values can be assigned to the constants $\alpha$ and $\beta$ and to the resin viscosity $\eta$. Most screws do not have constant dimensions over their full length, nor is the resin completely fluxed or at a uniform viscosity over the full length of the screw. The most significant area is that near the

Figure 1




EFFECT OF PRESSURE ON EXTRUDER OUTPUT

Figure 2. Effect of Channel Depth on Extruder Output

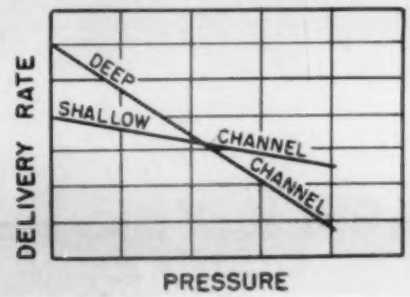
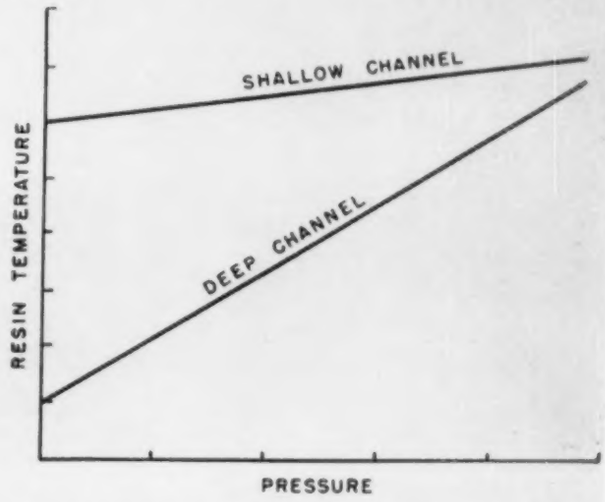
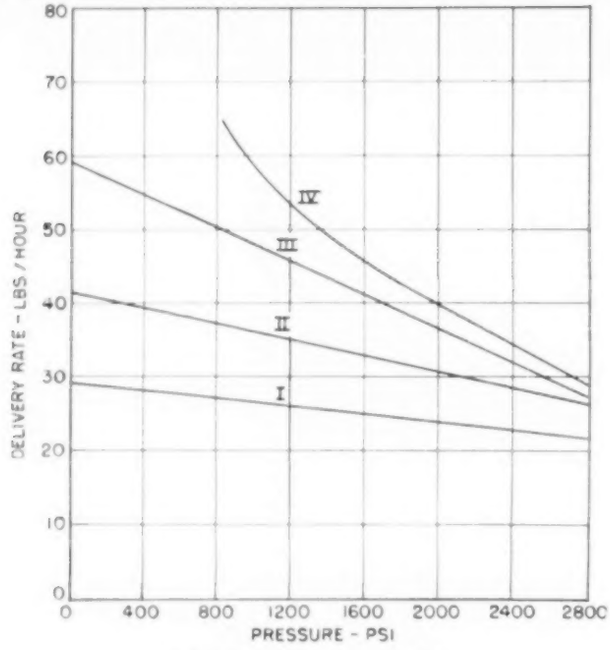



Figure 3




EFFECT OF CHANNEL DEPTH ON RESIN TEMPERATURE

Figure 4




DELIVERY RATE vs PRESSURE

Figure 5. Effect of Resin Viscosity on Extruder Output

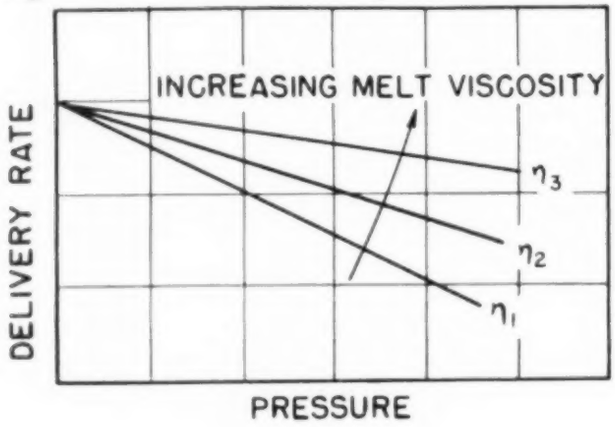
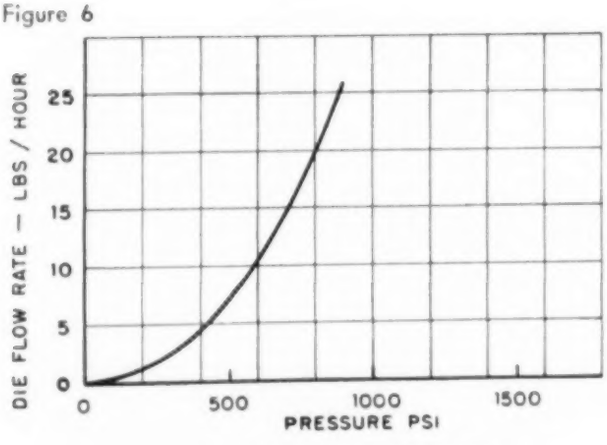
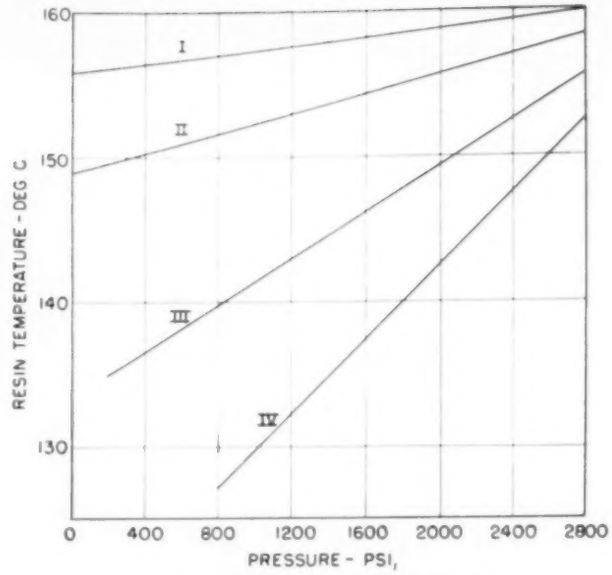



Figure 6



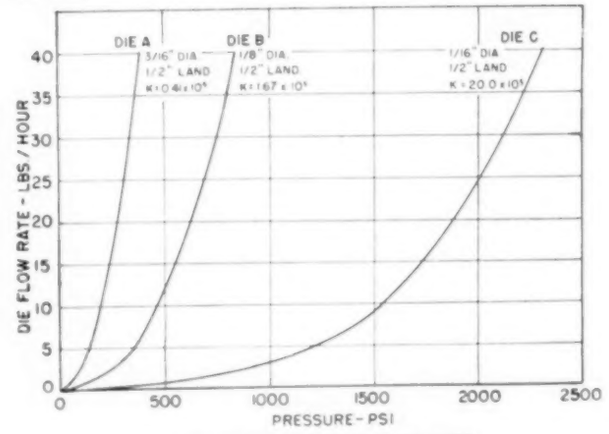

FLOW RATE VS. PRESSURE

Figure 6-B



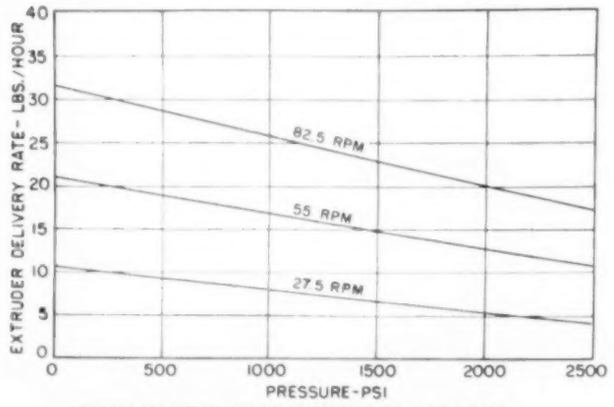

RESIN TEMPERATURE vs PRESSURE

Figure 7




EFFECT OF DIE RESISTANCE ON FLOW RATE

Figure 8




EFFECT OF PRESSURE ON EXTRUDER DELIVERY RATE

discharge end of the screw, usually in the last few turns of the thread, and in this area the material is generally considered to be in a molten state and at a fairly uniform temperature and viscosity. If a metering type screw is considered, in which the dimensions of the last three or more turns are constant, relatively simple expressions for $\alpha$ and $\beta$ are as follows:

$$\alpha = \tfrac{1}{2}\ \pi\ D\ hS\cos^2\phi \qquad (2)$$

$$\beta = h^3 S \sin\phi\cos\phi\ /12L \qquad (3)$$

where D = screw diameter
h = channel depth
$\phi$ = helix angle
L = effective screw length
S = channel width along axis = Pitch − thread width

The value of $\alpha$ is one half of the volume of the output thread and it is seen that this value, and therefore the open discharge rate, increases linearly with the channel depth, h. The effect of channel depth on back flow is much more pronounced, however, $\beta$ increasing as the cube of the depth. Increasing the channel depth therefore results in a higher delivery rate at low pressures (large dies), but the back flow may be increased to the extent that the output at high pressures (small dies) is actually reduced. This is illustrated in Figure 2.

A further result of an increase in channel depth is a reduction in mechanical heat development and resin temperature, particularly at low back pressures, as shown in Figure 3. This frequently leads to impaired surface quality.

Typical data for several 2.0" metering type and decreasing pitch type screws operated at 48 RPM with a cylinder temperature of 160 C and a screw temperature of 100 C are shown in Figure 4. Screw I gives the lowest delivery rate because of the shallow channel but the highest resin temperature at all pressures. This screw gives good quality under practically all conditions. At the other end of the scale, screw IV gives high output rates at low pressures, but very poor quality, often unfluxed material. This screw is of little value except for operation with small dies (high pressures). Screws II and III give intermediate delivery rates and quality levels.

Breaker plates and screens introduce additional resistance to flow, thereby increasing the back pressure and providing some measure of control over mechanical heat development and extrusion quality. Heavy screen packs may be beneficial, even essential, in extrusion of large sections with a deep channel screw, although it must be recognized that a reduction in output rate will result.

Returning to the flow equation (1), it is seen that an increase in resin molecular weight or melt viscosity should decrease the back flow and therefore raise the output rate for a given pressure level. The open discharge rate is not affected. This is illustrated in Figure 5.

The above discussions cover mechanisms taking place in the extruder itself, with screen packs and dies considered only as resistances which govern the amount of pressure and mechanical heat developed by the screw. Effects of the die on extruder operating characteristics are now considered.

The general condition for fluid flow through a die is given by the following relation:

$$Q = \Delta P / K\eta \qquad (4)$$

where: Q = volume rate of flow
$\Delta P$ = pressure drop across the die
$\eta$ = fluid viscosity
K = resistance constant

Values of the resistance constant, K, for dies of different configuration are as follows:

circular die $K = 128\,(L + 4D)\ \pi D^4$ (5)

slit die $K = 12L\ Wt^3$ (6)

tubular die $K = 12L\ Cmt^3$ (7)

where: D = diameter, circular die
L = land length
W = die width, slit die
t = die opening, slit die
t = wall thickness, tubular die
Cm = mean circumference, tubular die

If the resin viscosity, $\eta$, were a constant, it is seen that the die flow equation (4) would be represented by a straight line through the origin on a flow rate versus pressure plot. Actually, the viscosity of polyethylene is not constant for a given temperature and molecular weight, but depends, in addition, upon the pressure and velocity in the die. This results in die characteristic curves which are parabolic in nature, as shown in Figure 6 and 6-B.

Examination of the die resistance equations, (5), (6), and (7), shows that the resistance increases with increasing land length and with decreasing cross sectional area. This gives rise to a family of curves for dies with different resistance as shown in Figure 7 for Bakelite polyethylene DYNH (2.0 melt index) at 200 C.

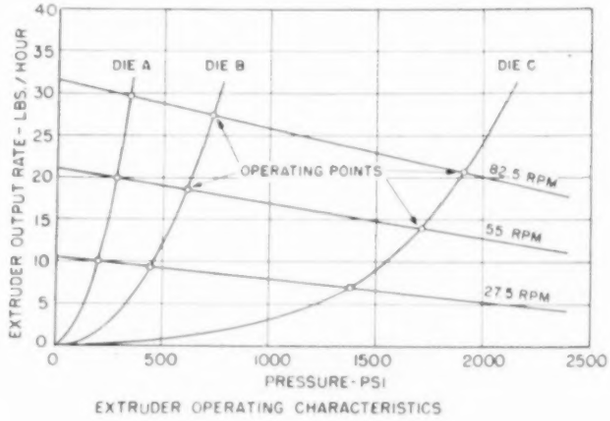
It will be recalled that the extruder delivery rate depends on the pressure developed in the head (as a result of the die restriction) in the manner illustrated in Figure 8 for extrusion of DYNH polyethylene in a 1.5" extruder at 200 C.

By super-imposing Figure 7 on Figure 8, the operating characteristics of the extruder, including the die, are completely described. This is shown in Figure 9.

Die A (3/16" dia., 1/2" land length) or anything larger would be considered a low resistance die, generally requiring pressures under 500 psi. Dies for large rods, heavy wall pipe or tubing, 40 mil and thicker sheeting and heavy contour sections in general fall in this category. Die B (1/8" dia., 1/2" land length) is of medium resistance (500-1500 psi). This range includes that for a film die having an opening on the order of 20 mils. High resistance such as that shown for Die C (1/16" dia., 1/2" land length) are encountered primarily in small diameter or thin wall wire insulation.

*In Part II appearing next month, Mr. Maddock will discuss some of the effects of extruder operating variables. Included will be discussions of such factors as effect of resin temperature and resin viscosity on extruder output and the effect of die resistance, resin viscosity, mechanical work and cylinder temperature on resin temperature.*

Figure 9




EXTRUDER OPERATING CHARACTERISTICS

cussion is Hostalen P.F. made by Farbwerke Hoechst in Germany. Outputs of 75 lbs. and 90 lbs. hr. were obtained at screw speeds of 14 and 20 RPM respectively.

**ULTRASONIC INSPECTION BY PULSED TRANSMISSION — R. E. Seaman.**

Description of a system to produce ultrasonic waves and the method employed to test molded products for cavities and cracks. The great attenuation in plastics makes it difficult to inspect large moldings by the reflection technique. The transmission technique using a series of pulses of ultrasonic energy is much more successful. The emergent energy is reconverted into electrical energy and the percentage transmission is then easily measured. The experimental equipment was tested with molding that contained a known number of holes of various dimensions. The scanning device found all holes; it is estimated that with this apparatus moldings of 9 to 12 inches in thickness could be examined.

**NEW 3-IN SINGLE SCREW EXTRUDER — Anonymous.**

More and more engineering firms are getting into the act and building their own version of the best extruder. The one described here is produced by Barnaby Engineering Co., Bexley, and Kent. The machine appears to be solidly built but does not seem to have revolutionary new features.

★

## RUBBER AND PLASTICS AGE

**Vol. 37, No. 7, July, 1956**

Abstracter: Watson C. Warriner

**AIRSLIP FORMING—Staff Written).**

Airslip forming is an improved version of drape-forming developed by the manufacturers of the well known "Formvac" range of vacuum-forming machines.

The principle involves the utilization of the air trapped between the fixed preheated sheet and the rising mold. The technique is reported to give:

(a) Excellent gauge distribution in the finished item.
(b) Minimum edge trim.
(c) Molecular orientation in two directions.
(d) Increased depth of draw.

Sketches and photographs are included to illustrate the technique.

**CATALYSTS FOR LOW PRESSURE ETHYLENE POLYMERS — (Staff Written).**

A discussion of the catalyst systems employed in the manufacture of Ziegler and Phillips type ethylene polymers.

**A CAR FOR A STAR—(Staff Written).**

Method of fabrication including illustrations for a glass fiber reinforced polyester resin plastic body for a small car.

★

## ITALY

### POLIPLASTI

**Jan., Feb., 1956**

Abstracter: Alfred L. Alk

**REINFORCED PLASTICS IN THE AIRCRAFT INDUSTRY. Luigi Dogliotti.**

A detailed review of the history of all types of plastics in the aircraft industry, including a much broader range than is indicated in the title. The article indicated where and how the plastics are used and what materials they replace, including reasons for the replacement.

**HIGH FREQUENCY SEALING OF THERMOPLASTIC MATERIALS Ciro Di Piero**

A very complete discussion of electronic sealing, how it is accomplished, what equipment is required, and the advantages of each type over the other. The article deals specifically with the following aspects of sealing: 1—the several kinds of sealing electrode assemblies. 2—mechanical requirements for good sealing. 3—electrical requirements. 4—sealing with separate thermal and pressure cycles. 5—other required equipment.

**POLYMERS AND CO-POLYMERS OF VINYL BROMIDE. Gordon Blauer**

Research on polyvinyl bromides has lagged because of the color sensitivity of vinyl bromide to slight heating and the absence of known inhibiting agents. However, copolymers were prepared in the hope of hindering the discoloration by introducing a second monomer between the reactive groups. Pure monomers were prepared and reacted under controlled conditions which are described, and molecular weights, bromine content and rates of reaction were determined. Copolymers were then prepared with vinyl acetate, methylmethacrylate and styrene. Sample injection moldings were prepared from the vinyl bromide—methyl methacrylate copolymer which was color stable up to about 200-250C. Pure polyvinyl bromide decomposes above 100 C. Further work is proposed now that procedures have been developed for preparation and identification of the reactants.

**A Hit At The Plastics Exposition**

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## SPE Regional Conferences

### 1. Epoxy Resins

Since the technology of epoxy resins has made such rapid advances in the Los Angeles area, the Southern California Section of the Society of Plastics Engineers has planned a one-day symposium on this subject. Both an introduction to the field and the latest information for the process or materials engineer will be included.

The symposium will be held on November 16 at 8:30 A.M. at the Institute of Aeronautical Sciences, 7660 West Beverly Boulevard, Los Angeles. The registration fee is $5.00, including luncheon and a booklet containing the symposium papers.

**Subjects Covered:**

**Three Epoxy Resin Systems for Elevated Temperature Use and the Effect of Cure Cycles on Properties,** R. M. Maybee, Shell Chemical Corp.

**The Chemistry of Modifiers for Epoxy Resins and Their Effect on Properties,** Keith Cranker, Thiokol Chemical Corp.

**Epoxy Resin Hardener Systems,** George Firth, Applied Plastics.

**High Temperature Anhydride Cures,** John Delmonte, Furane Plastics, Inc.

**High Temperature Liquid Amine Hardeners,** Joseph Philipson, Chemical Process Co.

**Dermatosis and Epoxy Systems,** Elliot N. Dorman, Ciba.

**Thermal Expansion of Filled Epoxy Resins,** J. E. Carey, Shell Chemical Corp.

**Glass Fabric Finishes,** Sam G. Salzinger, Coast Manufacturing and Supply Co.

**Epoxy Laminates: Production Problems and Techniques,** Guy Libly, Douglas Aircraft Co., Inc.

**Epoxy Laminates from Preimpregnated Reinforcements,** Bruce Godard, Bakelite Co.

**Epoxy Adhesives,** John R. Boetto, North American Aviation Inc.

Advance Registration—$5.00—Includes Luncheon And a Booklet Containing the Symposium Papers

**Send Inquiries and Registration Fee To:** Society of Plastics Engineers (Southern California Section) c/o Paul Erskine, 315 East Washington Boulevard, Los Angeles 15.

### 2. Plastics for Electronics

The New England Sections of the Society of Plastics Engineers will hold its first one-day technical session early in 1957 at the Massachusetts Institute of Technology, Cambridge, Mass. Plans are set to have this New England One-Day Technical Session an annual event. The topic for this year will be "Plastics for Electronics."

This symposium will be of particular interest to all manufacturers and processors of plastics and to the electronics industry as well as to small manufacturers of electronic components. Of exceptional interest to the manufacturers will be an opportunity for them to gain an insight into the plastic needs of the electronics industry, and to pose pertinent questions to an assembly of experts.

This conference is being jointly sponsored by the following New England Sections: Connecticut, Eastern New England, Pioneer Valley, Rhode Island and Southeastern Massachusetts, Western New England.


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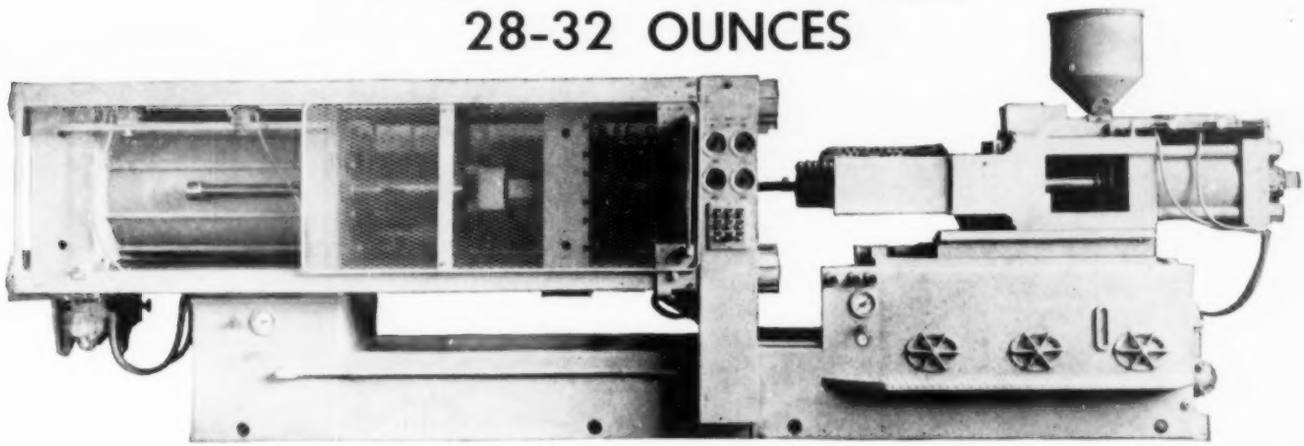

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# book reviews

## Factory Electrification

**By F. T. Bartho and C. H. Pike. Published by Philosophical Library, New York. 398 pages, $12.**

As the authors have stated, the book provides a general guide to the selection and use of electrical equipment for factories. The book would be of great value to engineers concerned with the installation and maintenance of electrical plant and management personnel; however, to use the book, the user needs to have a good knowledge of the fundamentals of electricity. Information on both American and British electrical requirements is contained in the book.

Chapter One gives an exposition on the power requirements, the use of a works generating plant or public supply conditions and power distribution systems. Each subject is further broken down into the important factors and their requirements, as to definition, types and sizes.

Chapters #2, 3 and 4 deal with the main power distribution system in a factory. The type, functioning and use of switchgear is thoroughly discussed along with the principles of construction, operation, installation and maintenance of transformers. In discussing the wiring system the authors point out that in existing factory power systems certain economical changes are possible to increase power transmission by changing to different types of equipment.

The remaining five chapters deal with the different types of both A.C. & D.C. motors. This section fully covers the principles, characteristics and speed control equipment of several types of induction motors, synchronous motor and how they improve power factor in a factory, and D.C. motors. There are several tables to use in determining the current required by a motor, size of motor for specific applications, and general characteristic curves for all types of motors.

The authors' bibliography is an interesting selection of the outstanding contributions to the subject.

**J. C. Stansel**

## Polyethylene, Volume IX of High Polymers

**By R. A. V. Raff and J. B. Allison. Published 1956 by Interscience Publishers, 250 Fifth Ave., New York 1, N.Y. 551 pages, $16.**

The polyethylene boom hasn't even begun to slack off, and interest in this versatile plastic is at an all time high. Hence the appearance of **Polyethylene** is well-timed and will be welcomed by many as providing the most complete and authoritative account of polyethylene to be found in a single volume.

Chapter I on historical development traces the rise of polyethylene from the first pioneer patent issued in 1936.

Ethylene, chemical and physical properties, is the subject of the second chapter. The various methods of manufacture are discussed.

The polymerization of ethylene in the gas phase and in bulk is the topic in chapter three. Methods of polymerization, conditions and many catalysts are well covered, providing a good review article of the work in this field. Since especially the newer low pressure polymerization methods are still in the process of rapid development and modification, and details of some of them still under cover, the discussion can not be expected to be complete, and there will be much to be added in the next few years. Everything considered, this chapter is remarkably done, and will be of exceptional interest.

The modified polyethylenes have a 49 page chapter to themselves. Telomers, graft polymers and various copolymers as well as halogenated and otherwise reacted polyethylenes are described. Chapter five is the chapter on molecular structure and its effect on properties, making it the most important chapter to the chemists working on polyethylene, and to the scientifically-minded molder who wants to know why the various polyethylenes behave as they do.

The physical properties of polyethylene, solvent resistance, environmental cracking and weathering, porosity and permeability, electrical properties, strength and the like are discussed in chapter six, and the analysis and testing of polyethylene in chapter seven.

The molder and extruder will be most interested in chapter eight, "Processing and Handling of Polyethylene," and chapter nine, "Uses and Applications of Polyethylene".

The book ends with a summary of polyethylene production and producers, and a list of 1152 references.

"Polyethylene" is well-written and does a good job of covering the pertinent literature, especially the patent literature. This volume is a worthy addition to Interscience's monumental series on high polymers.

**Jesse H. Day**

## ABACS Or Nomograms

**By A. Giet Philosophical Library, 15 East 40th St., New York 16, New York. 225 pages, $12.**

Engineers have long used nomograms as the easiest and fastest way of finding the value of one (or more) variable, when the values of other variables are arbitrarily chosen. Although the construction of each nomogram is usually a special case by itself, nevertheless the number of standard methods of construction are limited. ABACS is an outline and discussion of the various kinds of nomograms and how to construct them. The ground covered includes, relations between two variables, contesian ABACS, alignment charts based on parallel coordinates, charts **not** based on parallel coordinates, and relations between $\eta$ variables when $\eta$ is greater than five.

The choice of methods and choice of type of nomogram to be constructed is discussed in the appendix.

For anyone wanting to investigate the possible usefulness of nomograms, or for anyone who uses them, this book will provide a lucid and intelligent explanation of how to choose, construct and use nomograms. A number of exercises are included, so that the reader can practice and assure himself that he indeed has mastered each section of material. This is a valuable and useful book for any engineers.

**W. W. Birdsmith**

## FRANKLY SPEAKING

Dear Friends:

Last month I talked to you about HEADLINES and worked myself into a "tizzy" over the misunderstandings generated by the inaccuracies of many of them. I have been reading more headlines about ANTI-TRUST SUITS being filed by the Department of Justice of our Federal Government. However, I have not confined this reading to just the headlines. We have a good neighbor in Fort Wayne—the Fruehauf Trailer Company—and I was amazed to see that a suit has been filed against them because they have grown large and absorbed several smaller companies. The amazing part was that the Government has gone back 9 years to declare that an acquisition made then was violation of the Anti-Trust Laws. This seems like a long time for the Government to wait to decide that an illegal action was taken. Fruehauf's fault seems to be the same as the Bus Division of General Motors Corp. They are too successful.

From the point of view of the layman gleaned from the news releases, it appears that Uncle Sam is saying to Fruehauf, General Motors and others that they have too large a share of the market for their particular items. Now, I am not prepared to argue that there are not instances where one of these large companies has not taken advantage of their bigness and brought a little pressure to bear so that they received an order. However, this is somewhat beside the point of what I am trying to say.

I maintain that it is not the prerogative of any Government agency to decide how much or how little business any particular business enterprise may have. We should ask whether the Government's action is an effort to allocate business or is it an honest effort at regulation.

So long as there are a number of companies in the same line of business, we, the public, should have free choice of whom we wish to patronize. That choice will naturally be based on price, quality and service. That business which provides the best combination of these three elements SHOULD enjoy the greater patronage.

The function of Government is to see that you and I obey the rules of the game. The writing of these rules is to be done by our duly elected representatives and we owe it to ourselves and posterity to see that the rules are kept as simple as possible. In my opinion, if all of us observed just one rule—THE GOLDEN RULE—there would be little need for the multiplicity of regulations and rules now in existence.

Yours for better living with Plastics

Wayne I. Pribble

## Society of Rheology 1956 Annual Meeting

The Society of Rheology will hold its 1956 Annual Meeting in Pittsburgh, Pennsylvania, on November 7-9, 1956. The technical sessions will be held at the Mellon Institute, and the meeting hotel will be the Webster Hall.

Among the papers scheduled for presentation are ones covering such topics as adhesion, the effect of hydrogen on metals and metal alloys, methods for the experimental determination and theoretical evaluation of viscosity data, and the mechanical rupture of polymeric materials.

An important feature of the meeting will be the award of the Society's Bingham Medal. This will occur on Thursday evening, November 8th, in connection with the Social Hour planned for the meeting.

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# PRODEX EXTRUDERS

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## European Extruder Design . . .

(Continued from Page 29)

As was mentioned above, the barrel temperature settings become lower for comparable speeds as the diameter of the machine increases. This means, therefore, that to keep material temperatures within reasonable limits, barrel cooling would be necessary on a large machine at a lower screw speed than for a smaller machine. Furthermore, because of the lower barrel surface to volume ratio on a large machine as mentioned above, cooling becomes more difficult and the possibility of keeping material temperatures down as the speed of a larger machine is increased becomes more and more difficult. It therefore, seems that the screw speed limitations discussed earlier for 2½" machines become more stringent as the size of the machine increases. Therefore the 2-1 increase in maximum speed which was considered a possibility for the 2½" machine becomes less and less possible as the size of the machine increases.

## Conclusions

It is hoped that the results of these experiments have helped to clarify to a certain extent some of the problems connected with the design of single screw extruders.

In the beginning it was mentioned that the double screw extruder is a more positive piece of equipment, if the time taken for the material from the feed to the delivery can be accurately controlled and if the heat imparted to it could also be controlled. The experimental work carried out on single screw extruders has, on the whole, confirmed existing theoretical work. It is felt, therefore, that the most important conclusion we can draw is that the single screw extruder, with correct design, can be made into an accurate and docile instrument in which the passage of the material and the heating of the material can be fairly accurately controlled and varied to suit conditions and requirements.

It is also hoped that these experiments have shown that with materials such as Polythene, cellulose acetate, polystyrene, provided it is fed as granular material, the output, size for size, of a single screw extruder is greater than that of a double screw extruder.

It could be suggested that an increase in the screw lengths and barrel length of a double screw extruder would increase heating time and thus output, but in this case mechanical limitations, bearing limitations, would make an appreciable improvement rather problematic. To increase the speed of a double screw extruder would not improve output because of the heat limitations. It is felt, therefore, that as far as output is concerned, especially with materials with reasonable heat stability, the double screw extruder has come up against very serious limitations.

As far as the single screw extruder is concerned, it is felt that with more powerful drives, sectionalized barrel cooling and more accurate temperature control, present outputs can be improved upon. It is envisaged that an increase of screw speeds of 50-75% over existing maximum speeds could also contribute to a further improvement of output.

As far as screw design is concerned, it is felt that the tendency is to design tailor-made screws for particular materials and die combinations and this contributes further to increased output and qualitative efficiency.

## References

(1) Grant, D. and Walker, W., Plastics Progress, London, Iliffe & Sons Ltd., 1951.

(2) Rowell, H. S., and Finlayson, D., Engineering, 114, 606 (1922); 126, 249, 385 (1928).

(3) Rigby, Z., British Plastics, 23, 100 (1950).

(4) Maillefer, Ch., Etude Theorique et Experimentale sur le Functionnement des Boudineuses. Imprimerie la Concorde (1952).

(5) Carley, J. F., Mallouk, R. S. and McKelvey, J. M., Ind. Eng. Chem. 45, 974 (1953).

(6) Meskat, W., Theorie der Stoffbewegung in Schneckenmaschinen Kunststoffe, page 89, March (1955).

(7) Gaspar, E., Fundamental Problems of Single Screw Thermoplastic Extruders.

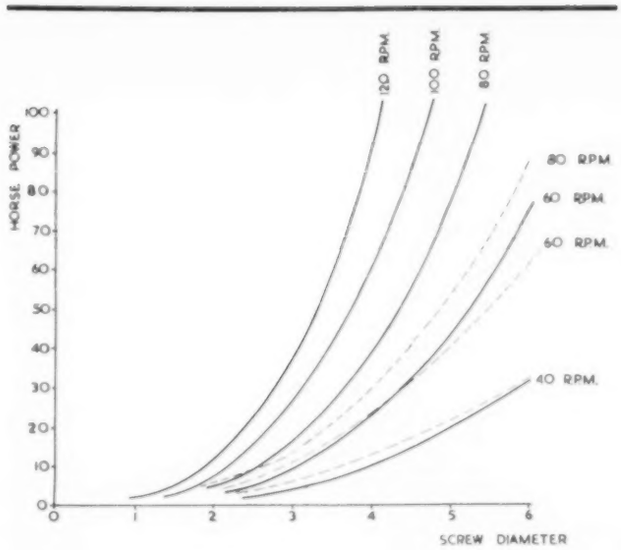


FIG. 12. ACTUAL SCALE UP RELATIONSHIP.

## Rhode Island Golf Outing

Glenn A. Tanner

The annual golf outing of the Rhode Island and Southeast Massachusetts section was held Thursday, August 23rd, at the Pawtucket Country Club. The date found nearly forty members between vacations and able to attend.

Considerable work was accomplished in planning the affair by chairman Sydney Lohman of Lester-Phoenix Inc., Edward Rose of Plastics Engineering Co., Pawtucket, as president, and Charles Chrones of Hassenfeld Bros. as secretary. Their exacting arrangements not only produced an excellent roast beef dinner for the banquet but also produced a glorious sunshiny day for golf in the afternoon.

A multitude of prizes were awarded to the fortunate handicap golfers. Low gross was obtained by Mr. Arthur Staff and Mr. P. Thorson. Low net honors went to W. Paris as did the high gross award.

Prizes for the affair were furnished by the section and also included prizes donated by William J. Monahan of Dow Chemical Co., W. R. Conroy of Durez Plastics, John E. Lynch of Celanese Corp. of America, Robert Johnson of Monsanto Chemical Corp., Lloyd Evans of Allied Dye, and trophies furnished by Marine Plastics Inc.

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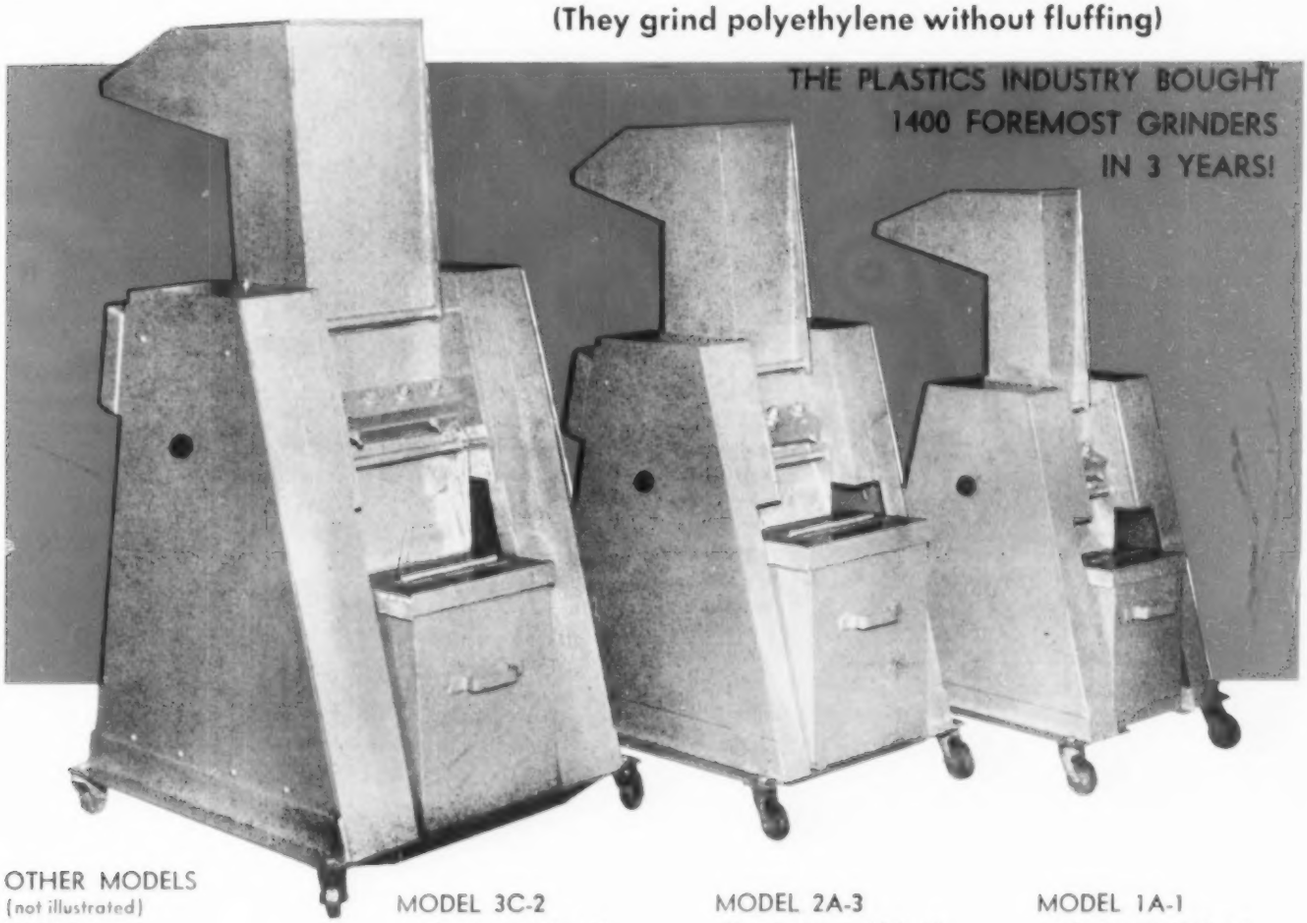


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We have an exceptional opportunity for a man with 2-5 years' experience in application research in processing, compounding and formulating of polyvinyl chloride. We prefer experience in calendered plastics, either film or sheeting. A familiarity with pilot plant and manufacturing operations is essential. This is a career opportunity with a progressive Northern New Jersey manufacturer. Excellent employee benefits. Send full resume including salary required to Box No. 3156, SPE JOURNAL.

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We are looking for a man with at least 5 years' experience in formulation, development and processing of calendered vinyl composition and plastisols. He must be familiar with plant equipment and operations, and have leadership potential and technical supervision experience. Press moulding operations experience desirable. A career opportunity plus excellent employee benefits with a progressive Northern New Jersey manufacturer. Send full resume including salary desired to Box No. 3256, SPE JOURNAL.

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Allied Chemical and Dye Corp., National Aniline Div. ---- 11
Allied Chemical and Dye Corp., National Aniline Div. ---- 59
American Cyanamid Co. ---- 16
Antara Div., General Aniline and Film Corp. ---- 7
Bakelite Co., a Division of Union Carbide and Carbon Corp. ---- 3
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The Borden Co., Chemical Division ---- 41
Detroit Mold Engineering Co. ---- 12
Frank W. Egan and Co. ---- 6
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National Aniline Div., Allied Chemical and Dye Corp. ---- 11
National Aniline Div., Allied Chemical and Dye Corp. ---- 59
National Distillers Products Corp., U. S. Industrial Chemicals Div. ---- 4
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Union Carbide and Carbon Corp., Bakelite Co. ---- 3
Union Carbide and Carbon Corp., Bakelite Co. ---- 8-9

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